SUMMARY
OF
RESEARCH
1996

Interdisciplinary Academic Groups

C3 - Dan C. Boger, Chair

Information Warfare - Fred Levien, Chair

Space Systems - Rudolf Panholzer, Chair

Undersea Warfare - James Eagle, Chair

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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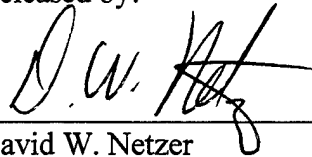This report was prepared for the Naval Postgraduate School, Monterey, CA.

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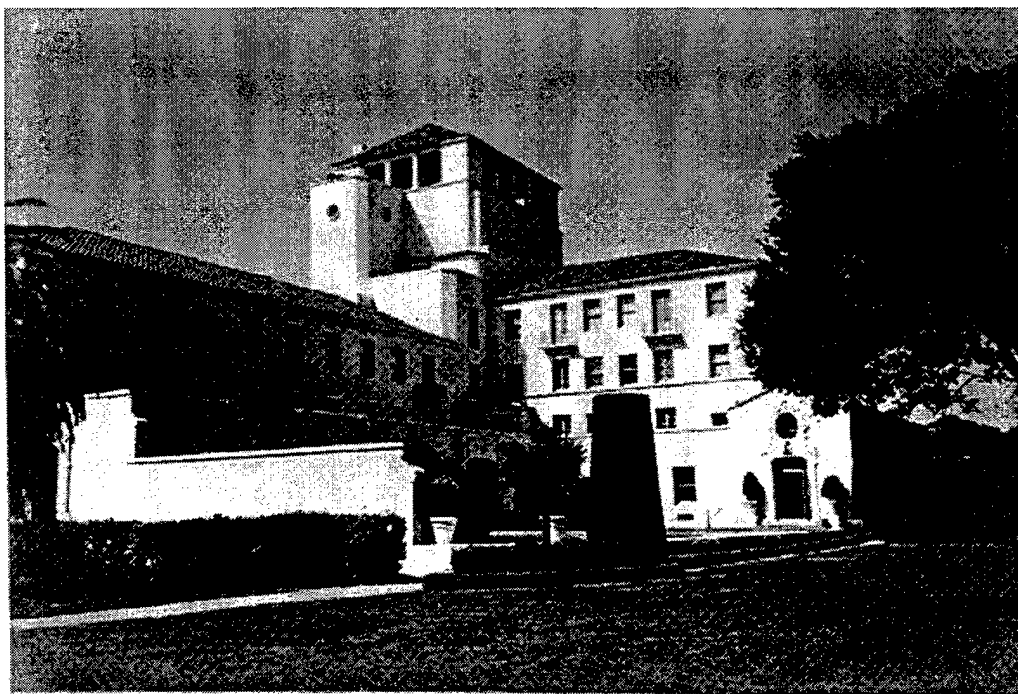
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13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Interdisciplinary Academic Groups. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis reports.

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INTERDISCIPLINARY ACADEMIC GROUPS

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of US and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.

CONTENTS

Preface

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.

- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.

- Apply faculty and student knowledge to enhance DoN/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

New technologies and policy changes will of course occur, necessitating changes in educational programs and stronger ties between the fleet and the support establishment. NPS must remain poised to face this challenge and to utilize emerging technologies and new policies within its curricula programs. Faculty, therefore, must stay abreast of these developments through a dynamic research program that helps fulfill the School's goals of excellence, uniqueness, and relevance.

The overall research program at NPS has three funded components. The Direct Funded Research and Institute for Joint Warfare Analysis Programs are institutionally funded within the School's operating budget. The Direct Funded Research Program is administered by the Associate Provost and Dean of Research. The Institute for Joint Warfare Analysis Program is administered by the Director of IJWA.

- The Direct Funded Research (DFR) Program provides funding to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.

- The Institute for Joint Warfare Analysis Research Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of faculty research.

- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The three research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

In 1996, the level of the research effort at the Naval Postgraduate School was 141 faculty workyears and exceeded 29 million dollars. Eighty percent of the research was funded by reimbursable sponsors and 20 percent was funded by the Naval Postgraduate School. Sixty-five percent of the work was performed for the Navy and the remainder was sponsored by other agencies, both DoD and non-DoD. A profile of the reimbursable program of the Command, Control

and Communications Academic Group is provided in Figure 1, Information Warfare Academic Group in Figure 2, Space Systems Academic Group in Figure 3, and Undersea Warfare Academic Group in Figure 4.
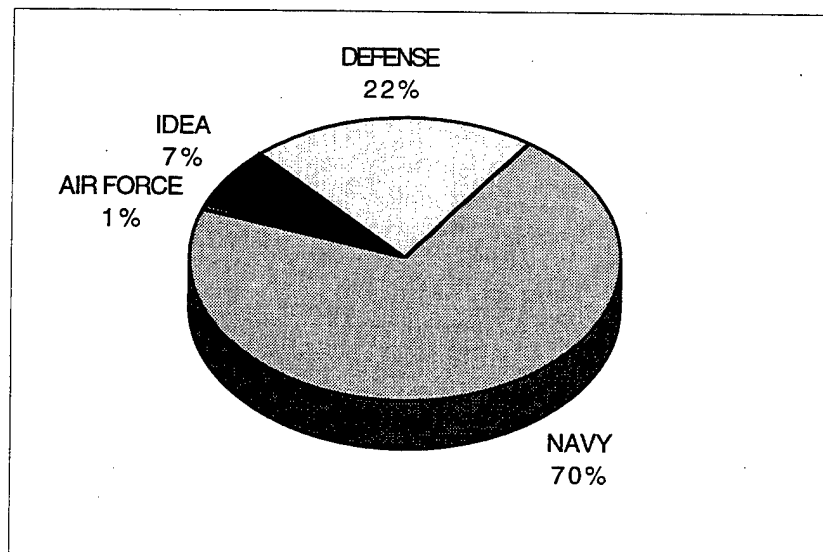
Size of Program: $801K
Figure 1. Command, Control and Communications Academic Group - Sponsor Profile
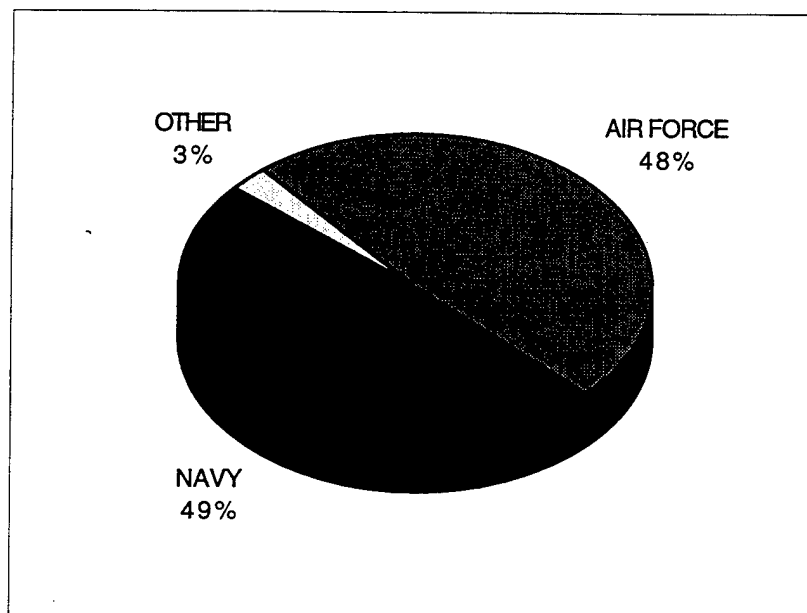
Size of Program: $121K
Figure 2. Information Warfare Academic Group - Sponsor Profile
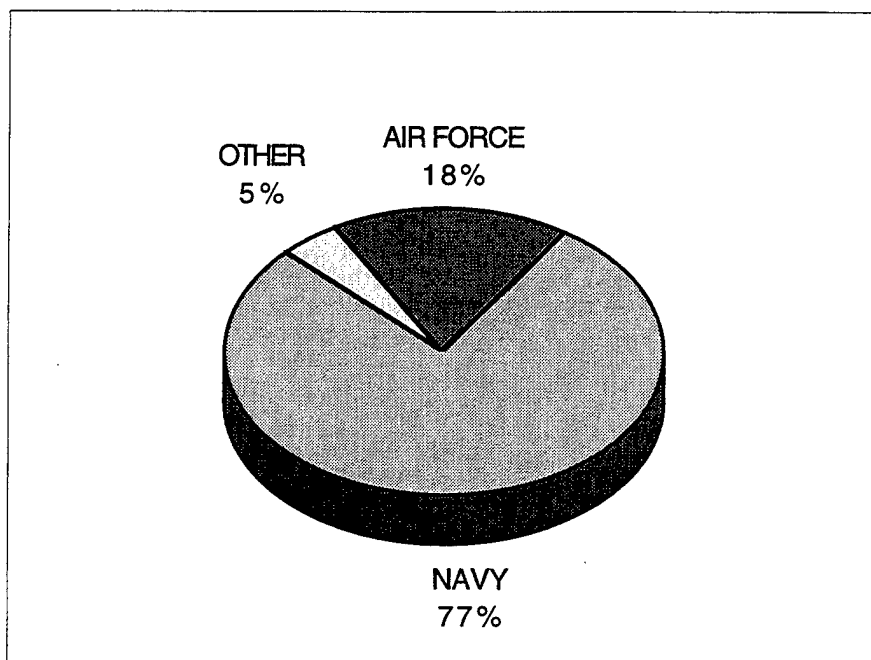
Size of Program: $1,129K
Figure 3. Space Systems Academic Group - Sponsor Profile
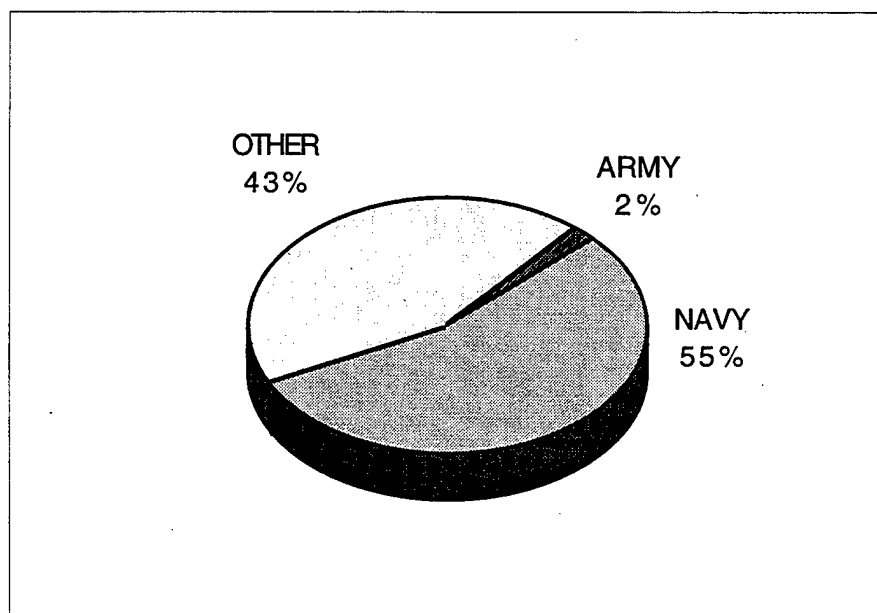
Size of Program: $585K
Figure 4. Undersea Warfare Academic Group - Sponsor Profile

Research at NPS is carried out by faculty in the School's eleven Academic Departments, four Interdisciplinary Groups and the School of Aviation Safety. In the pages that follow, research summaries are provided for projects undertaken by faculty in the Groups during 1996. An overview and faculty listing are provided as an introduction. A list of publications is also included, if applicable. Abstracts for thesis advised by Group faculty in 1996 complete this research summary.

Questions about particular projects may be directed to the Faculty Principal Investigator listed, the Department/ Group Chair, or the Department Associate Chair for Research. Questions may also be directed to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice) or research@nps.navy.mil (e-mail).

August 1997

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The Command, Control, and Communications (C3) Academic Group is an interdisciplinary association of faculty which consists of 25 faculty members who hold appointments in 9 departments/groups at the Naval Postgraduate School, plus the Curricular Officer. The C3 Academic Group has responsibility for the academic content of the Joint Command, Control, Communications, Computers, and Intelligence Systems curriculum and the Scientific and Technical Intelligence curriculum. C3 Academic Group faculty members carry out research in C4I systems, broadly defined, to support these two curricula.

During 1996, the C3AG consisted of the following members:

> Lieutenant Colonel Ernest K. Beran, USAF (39), Curricular Officer
> Professor Dan C. Boger (Command, Control and Communications), Chair
> Lecturer Rex A. Buddenberg (Systems Management)
> Professor Ralph N. Channel (National Security Affairs)
> Professor Kenneth L. Davidson (Meteorology)
> Professor Donald P. Gaver (Operations Research)
> Major John Gibson (Command, Control and Communications)
> Senior Lecturer Wayne P. Hughes (Operations Research)
> Lieutenant Commander Steven J. Iatrou (Information Warfare)
> Professor Carl R. Jones (Systems Management)
> Captain Frank Kelly (National Security Affairs)
> Associate Professor William G. Kemple (Command, Control and Communications)
> Associate Professor Christopher Layne (Command, Control and Communications)
> Professor Herschel H. Loomis (Electrical and Computer Engineering)
> Professor Orin E. Marvel (Command, Control and Communications)
> Associate Professor Gordon McCormick (Command, Control and Communications)
> Associate Professor Paul H. Moose (Electrical and Computer Engineering)
> Associate Professor John S. Osmundson (Command, Control and Communications)
> Professor Patrick J. Parker (Command, Control and Communications)
> Associate Professor Gary R. Porter (Command, Control and Communications)
> Associate Professor Craig Rasmussen (Mathematics)
> Professor Nancy C. Roberts (Systems Management)
> Associate Professor Timothy J. Shimeall (Computer Science)
> Professor Michael G. Sovereign (Command, Control and Communications)
> Associate Professor Donald V.Z. Wadsworth (Electrical and Computer Engineering)

An overview of the Command, Control, and Communications (C3) Academic Group research program follows.

Thesis Support for the Operational Support Office

Dan Boger continued his research with NPS thesis students into the potential benefits to the Joint Task Force Commander for real-time command and control of warfighting forces through the direct downlinking of information from sensors. By examining specific JTF-level scenarios, several alternative concepts of operation for directly-linked sensor information are compared to current, existing sensor information architectures. Measures of effectiveness focus on the tradeoff of latency for quality of information. Scenarios involving both generic command and control as well as targeting-quality information for specific weapons systems are being evaluated.

Support for TADMUS Experiments and Data Analysis

Michael Sovereign and Research Psychologist Susan Hutchins continued research support to the Tactical Decision Making Under Stress (TADMUS) Program, sponsored by Office of Naval Research. The objective of the TADMUS program is to apply recent developments in decision theory, individual and team training, and information display to the problem of enhancing tactical decision quality under conditions of stress. The specific research support in this project is being provided to Naval Command Control Communications and Ocean Surveillance Center Research and Redevelopment Division (NRaD), where the experiments are being conducted, and this support includes a decision support system, training strategies, and alternative human-machine interface concepts. Experimentation using specific anti-air scenarios is used to assess the effectiveness of the newly developed decision support system.

Adaptive Architectures for Command and Control

William Kemple and Michael Sovereign contributed to a four-year, continuing project whose objectives are to: extend twelve years of Navy decision-making research into the joint C2 arena; expand the domain beyond the frequently studied anti-air warfare arena; focus on adaptive architectures; and produce results ranging from purely theoretical to those that can be used by the operational forces in the near term. This project is the NPS portion of a government, industry, academe team formed by Office of Naval Research to carry out this program.

Command, Control, and Communications (C3) Analysis Techniques

William Kemple continued an on-going research project whose main objective is to identify research topics of current interest to the Marine Corps and match thesis students with these topics. Emphasis is on measuring C3 systems effectiveness and identifying futuristic C3 technologies which, if developed and implemented, might enhance MAGTF C3 capabilities and support the new Marine Corps Operational Maneuvers from the Sea (OMFTS) and Operation Other Than War (OOTW) concepts.

Application of Modern Computers, Interactive Array Processing Languages, and Graphics to Teaching and Research

William Kemple and Peter Lewis, Department of Operations Researach, continued a project to develop a methodology for using interactive array processing languages and graphics such as S-Plus and APL2/AGSS to allow analysts to rapidly and interactively produce the kinds of analysis previously obtained with the FORTRAN program SIMTBED and to produce vastly superior graphics for analysis.

GLIM for Approximate Estimation of Rate Functions in Non-Homogeneous Poisson Processes

William Kemple and Peter Lewis, Department of Operations Research, continued a project to investigate simple ways of using GLIM for approximate estimation of rate functions in non-homogeneous poisson processes and for simulation of processes similar to those that produced the historical data being analyzed.

Support for the Joint C4I Chair Professorship

Orin Marvel, the holder of the Joint C4I Chair Professorship sponsored by the Defense Information Systems Agency, continued his research in systems engineering for C4I systems and theater missile defense. He also continued his support of the Joint C4I Systems curriculum through further development of systems engineering projects and courses.

Targeting Underground Organizations

Gordon McCormick and Guillermo Owen Department of Mathematics developed a formal framework for evaluating the dynamics of sub-state conflict and used this framework to examine ways in which to improve our ability to target terrorist organizations.

Special Operations/Low Intensity Conflict (SO/LIC) Curriculum Teaching and Research Support

Gordon McCormick continued his project which provides instructional and research support to the students and faculty of the Special Operations Curriculum.

Command and Control of Underground Organizations

Gordon McCormick examined the functions, methods, and structures of underground systems of command and control. Specific examples are analyzed as cases.

Common Data Link (CDL) Interfaces to the Global Network Architecture

Paul Moose, Shridhar Shukla, Department of Electrical and Computer Engineering, and Gilbert Lundy, Department of Computer Science, continued their research into emerging high speed networking architectures and protocols for design of a seamless interface of the CDL to the global broadband network. The first goal is to use these architectures and protocols to develop a CDL-network interface for both ends of the data link. A ranking methodology based on a set of evaluation metrics is being developed and will be applied to the different alternatives identified. The second goal is to develop an implementation plan for integrating CDL into the DoD global network architecture. The plan being developed includes a verification of the integration concept along with assessments of protocol availability, interoperability, network management issues, and performance-related modeling and tradeoffs.

Global Broadcast System Testbed

Paul Moose began procuring equipment to support the installation of a downlink testbed for the Global Broadcast System (GBS) in the NPS System Technology Laboratory (STL).

HDR COFDM Modem

Paul Moose developed a MATLAB simulation of a COFDM modem and of maritime channel models at UHF for transmission of 1.5 Mbps in 450 Khz bandwidth.

Systems Engineering of Networked, Distributed Systems

John Osmundson continued a project whose objective is to develop analytical, and modeling and simulation techniques for the analysis, design, rapid prototyping, and tradeoff studies of complex, time-critical, and networked distributed systems. This project is a two-year effort which began in January 1995 and ended in December 1996.

THESIS SUPPORT FOR THE OPERATIONAL SUPPORT OFFICE
D.C. Boger, Professor
Command, Control and Communications Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this continuing project is to assess improvements in warfighter support which could occur due to the better availability of sensor information.

SUMMARY: Direct downlink of information to the Joint Force Commander (JFC) can provide enormous benefits in providing real-time command and control of warfighting forces and weapons systems. By examining specific JFC-level scenarios which focus on command and control as well as weapons systems, several alternative concepts of operation for sensor information processing and dissemination were compared with current, existing sensor information architectures. Primary measures of effectiveness focused on the tradeoffs between latency and quality of information received by the JFC/weapons systems. Enhancements to current architectures and systems were recommended.

THESES DIRECTED:

Arvanitas, S., "An Operational Assessment of Space-Based Situational Awareness," Master's Thesis, Naval Postgraduate School, September 1996.

Costello, E. and Gotham, G.A., "Overhead Non-Imaging Infrared (ONIR) Sensor-to-Shooter Connectivity Options for the Theater-wide Ballistic Missile Defense and Pre-Apogee Intercept From the Sea," Master's Thesis, Naval Postgraduate School, March 1996.

Frakes, P.F., "The Utility of a Long Dwell Imaging (LDI) Capability to Army Operations," Master's Thesis, Naval Postgraduate School, September 1996.

Selkirk, J.K., "The Future Intelligence Dissemination Architecture," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Battlespace Environments, Command, Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation

KEYWORDS: Concepts of operation, sensors, communications, networking

TACTICAL DECISION MAKING UNDER STRESS (TADMUS)
S.G. Hutchins, Research Psychologist
Command, Control and Communications Academic Group
Sponsor: Office of Naval Research and
Naval Command Control and Communication Ocean Surveillance Center

OBJECTIVE: The objective of the TADMUS program is to apply recent developments in decision theory, individual and team training, and information display to the problem of enhancing tactical decision making under conditions of stress. Products of this research will include a decision support system (DSS), and general principles for advanced decision support systems, a variety of training strategies that will attenuate the effects of stress on team performance, and human-computer interface concepts which maximize the effectiveness of tactical decision support systems under stressful conditions. The technology will be demonstrated and evaluated in the context of anti-air scenarios; general principles will be developed that will be applicable to other warfare areas. Experimentation is required to assess the effectiveness of the newly developed decision support system. This effort is in support of a six-year on-going effort.

SUMMARY: An experiment was conducted to examine the impact of the DSS on team performance. Eight expert Navy tactical decision making teams (with emphasis on the commanding officer (CO) and tactical action officer (TAO))

used either their current system alone or in conjunction with the prototype DSS. A within subjects factorial design was employed across four test scenarios such that each team performed two scenarios with the DSS and two scenarios without it. In addition to collecting objective data on tactical actions, display usage, voice communications, and subjective assessments (via questionnaires and a structured interview) were solicited from each CO and TAO at the conclusion of the test session.

PUBLICATIONS:

Englund, C.E., Harris, W.C., Weinger, M.B., Feher, B.A., Hutchins, S.G., Callan, J.R., and Kelly, R.T., "Performance-shaping factors (PSF): Considerations for human computer interface (HCI) design," Advances in Applied Ergonomics, Ahmet Ozok and Gavriel Salvendy eds., USA Publishing Corporation, West Lafayette, IN, 1996.

Hutchins, S.G., "Principles for Intelligent Decision Making," in Human Interaction with Complex Systems: Conceptual Principles and Design Practice, Ntuen, C.A., and Park, E.H., eds., Kluwer Academic Publishers, Norwell, MA, 1996.

Hutchins, S.G., Kelly, R.T., and Morrison, J.G., "Decision Support for Tactical Decision Making Under Stress," Proceedings of the 1996 Symposium on Command and Control Research and Technology, pp. 204-215, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Morrison, J.G., and Kelly, R.T., "Principles for Aiding Complex Military Decision making," Proceedings of the 1996 Symposium on Command and Control Research and Technology, pp. 186-203, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., and Hutchins, R.G., "Decision Support for Enhancing Tactical Air Situation Awareness," State-of-the-Art Report on The First Annual Symposium on Situational Awareness in the Tactical Air Environment, T. Assenmacher, K. Garner, & R. Schopper, eds., Patuxent River, MD, 4-5 June 1996.

Kemple, W.G., Hutchins, S.G., Kleinman, D.L., Sengupta, K., Berigan, M.C., and Smith, N.A., "Early Experiences with Experimentation on Dynamic Organizational Structures," Proceedings of the 1996 Symposium on Command and Control Research and Technology, pp. 847-857, Monterey, CA, 25-28 June 1996.

Kelly, R.T., Hutchins, S.G., and Morrison, J.G., "Decision Processes and Team Communications with a Decision Support System," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 216-221,. Monterey, CA, 25-28 June 1996.

Kelly, R.T., Hutchins, S.G., and Morrison, J.G., "Decision Processes and Team Communications with a Decision Support System," Proceedings of the Second International Symposium on Command and Control Research and Technology pp. 73-79, Market Bosworth, Warwickshire, U.K., 24-26 September 1996.

Morrison, J.G., Kelly, R.T., and Hutchins, S.G., "Impact of Naturalistic Decision Support on Tactical Situation Awareness," Proceedings of the 40th Human Factors and Ergonomics Society Annual Meeting, Philadelphia, PA, 2-6 September 1996.

CONFERENCE PRESENTATIONS:

Hutchins, S.G., "Lessons Learned on Improving Decision Making under High Stress," TapRoot Incident/Accident Investigation Conference, Nashville, TN, 24-26 July 1996.

Hutchins, S.G., and Hutchins, R.G., "Decision Support for Enhancing Tactical Air Situation Awareness," Presentation to The First Annual Symposium on Situational Awareness in the Tactical Air Environment. Patuxent River, MD, Wright-Patterson Air Force Base, OH, 4-5 June 1996.

Hutchins, S.G., Kelly, R.T., and Morrison, J.G., "Decision Support for Tactical Decision Making under Stress," 1996 Symposium on Command and Control Research and Technology, pp. 204-215, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Morrison, J.G., and Kelly, R.T., "Principles for Aiding Complex Military Decision making," 1996 Symposium on Command and Control Research and Technology, pp. 186-203, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Morrison, J.G., and Kelly, R.T., "Development of a Decision Support System Based on Analysis of Operational Decisions," Military Operations Research Society, Ft. Leavenworth, KS, 18-20 June 1996.

Kemple, W.G., Hutchins, S.G., Kleinman, D.L., Sengupta, K., Berigan, M.C., and Smith, N.A., "Early Experiences with Experimentation on Dynamic Organizational Structures," 1996 Symposium on Command and Control Research and Technology, pp. 847-857, Monterey, CA, 25-28 June 1996.

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Kelly, R.T., Hutchins, S.G., and Morrison, J.G., "Decision Processes and Team Communications with a Decision Support System," Second International Symposium on Command and Control Research and Technology, pp. 73 -79, Market Bosworth, Warwickshire, U.K., 25-28 September 1996.

Morrison, J.G., Kelly, R.T., and Hutchins, S.G., "Impact of Naturalistic Decision Support on Tactical Situation Awareness," 40th Human Factors and Ergonomics Society Annual Meeting, Philadelphia, PA, Human Factors Society, 2-6 September 1996.

OTHER:

Hutchins, S.G., "Principles for Aiding Complex Military Decision Making," Naval Command, Control and Ocean Surveillance Center, RDTandE Division, Technical Report 1718, San Diego, CA.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Human decision-making, human-system interface, human factors decision theory, human-in-the-loop simulation tactical decision-making, command, control and communications (C3)

ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL (A2C2)
W.G. Kemple, Assistant Professor
M.G. Sovereign, Professor
Command, Control and Communications Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: Part of a continuing project to conduct field, theoretical, and experimental research into flexible, adaptive organizational structures for Joint Task Forces, to develop theories and models that address reconfigurable organizational structures to support command decision making and command and control team performance and to develop a principled basis for organizational design of flexible command and control systems for joint operations in modern littoral warfare.

SUMMARY: During the current year, researchers at NPS, working jointly with researchers from civilian universities and industry, conducted the first two of an ongoing series of experiments. These experiments are integrated into the C4I Systems Evaluation course. The first experiment looked into the relationship between organizational structure and task type in joint operations in modern littoral warfare. Six-player teams represented the major command and control nodes of a joint amphibious task force. They played in both traditional and flattened command hierarchies. In each structure,

the scenarios required the players to compete (pairwise) for scarce assets which were either owned by one of the players competing for them or owned by a commander higher in the hierarchy. The main focus was to examine the effect that an intermediate-level commander would have on mediating the competition for the different types of assets and to gather information to support future model-driven experiments. The second experiment built upon the first and included a modeling component. A graph theoretic (pictorial) description of the mission was developed at NPS prior to the experiment and a concomitant analytical modeling effort by researchers at the University of Connecticut used this task graph to construct an optimal organizational structure in terms of inter-node coordination demands. A second organizational structure was developed at NPS using traditional military systems engineering approach. The experiment was conducted in three stages using six teams. In the first stage, all six teams played the same scenario, with three teams playing in each of the structures. The second stage immediately followed the first. Information about workload and other factors was gathered, the organizational structures were critiqued, and the teams were asked to redesign the organizations based on their recent experience. In the third stage, each team was presented two trigger events or vignettes. The first reduced the assets available to them and the second added an additional mission without increasing assets. The teams were then asked to redesign their organizations and task graphs.

To maintain currency in joint organizational ideas and issues, help formulate the research questions to be examined in the experiments, and help develop the experimental scenarios, NPS researchers have maintained a high level of field research since project inception. This year, they participated in planning for Nimble Vision, played in a Revolution in Military Affairs Wargame, served as a member of a Joint Warfighting Center workshop on formation of a Joint Task Force and as members of the two meetings of the Naval Doctrine Development Committee, and participated in an ONR sponsored summer study on C4ISR and precision weapons and hosted the follow-on workshop. They also participated in and co-chaired a workshop on measurement for command and control experimentation and a NATO C3I modeling measures workshop.

PUBLICATIONS:

Kemple, W., Kleinman, D., and Berigan, M., "A2C2 Initial Experiment: Adaptation of the Joint Scenario and Formalization," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 837-846, 1996.

Kemple, W., Hutchins, S., Kleinman, D., Sengupta, K., Berigan, M., and Smith, N., "Early Experiences with Experimentation on Dynamic Organizational Structures," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 847-857, Monterey, CA, 25-28 June 1996.

Kleinman, D.L., Young, P.W., and Higgins, G., "The DDD-III: A Tool for Empirical Research in Adaptive Organizations," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 827-836, Monterey, CA, 25-28 June 1996.

Porter, G.R., "Joint Simulation Assessment," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 819-826, Monterey, CA, 25-28 June 1996.

Sengupta, K., Berigan, M., Kleinman, D.L., and Serfaty, D., "Architectures for Command and Control Organizations: Dimensions of Task and Organizational Structure," Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 281-287, Monterey, CA, 25-28 June 1996.

CONFERENCE PRESENTATIONS:

Kemple, W., Kleinman, D., Smith, N., and Entin, E., "Adaptive Architectures for Command and Control (A2C2)," 64th Military Operations Research Society Symposium, Ft. Leavenworth, KS, 18-20 June 1996.

Kemple, W., Kleinman, D., and Berigan, M., "A2C2 Initial Experiment: Adaptation of the Joint Scenario and Formalization," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Kemple, W., Hutchins, S., Kleinman, D., Sengupta, K., Berigan, M., and Smith, N., "Early Experiences with Experimentation on Dynamic Organizational Structures," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Kleinman, D.L., Young, P.W., and Higgins, G., "The DDD-III: A Tool for Empirical Research in Adaptive Organizations," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Porter, G.R., "Joint Simulation Assessment," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Sengupta, K., Berigan, M., Kleinman, D.L., and Serfaty, D., "Architectures for Command and Control Organizations: Dimensions of Task and Organizational Structure," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

THESES DIRECTED:

Berigan, M. C., "Task Structure and Scenario Design," Master's Thesis, Naval Postgraduate School, June 1996.

Higgins, G.S., "The DDD-III: A Research Paradigm for Abstracting Joint C3 Scenarios for Tier-1 Experiments," Master's Thesis, Naval Postgraduate School, June 1996.

Smith, N. A., "Performance Measure Analysis of Command and Control Organizational and Task Structures," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Human Systems Interface

KEYWORDS: Command and control, joint operations, organizational experiments

COMMAND, CONTROL AND COMMUNICATIONS (C3) ANALYSIS TECHNIQUES
W.G. Kemple, Assistant Professor
Command, Control and Communications Academic Group
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: This is an ongoing research project whose main objective is to identify research topics of current interest to the Marine Corps and match up thesis students with these topics. Emphasis is on measuring C3 systems effectiveness and identifying futuristic C3 technologies which, if developed and implemented, might enhance MAGTF C3 capabilities and support the new Marine Corps Operational Maneuver From the Sea and Operations Other Than War concepts during the 21st century.

SUMMARY: Field and literature research continued to identify and document techniques for developing C3 measures of effectiveness (MOEs) and documenting futuristic C3 technologies. As part of this effort, the PI travelled to the Commandant's Warfighting Laboratory and participated in the experimental design for the upcoming Hunter Warrior Advance Warfighting Experiment. A theses previously directed under this project (Mason, 1995) which presents methods for developing measures of effectiveness for C4I systems was converted to HTML format and posted to a WWW page.

Through this project and the A2C2 project above, hardware to host the MAGTF Tactical Warfare Simulation (MTWS) to support USMC related research was obtained by the Systems Technology Laboratory and the software is scheduled for installation in February 1997.

THESES DIRECTED:

Berigan, M.C., "Task Structure and Scenario Design," Master's Thesis, Naval Postgraduate School, June 1996.

Duff, D.A., "Wireless Applications for Marine Air Ground Task Forces," Master's Thesis, Naval Postgraduate School, June 1996.

Hague, T.R., "LeatherNet: An Evaluation of the Marine Corps' Virtual Reality Simulator for Ground Combat Units," Master's Thesis, Naval Postgraduate School, September 1996.

Pellegrino, S.C., "United States Marine Corps Military Occupational Specialty (MOS) Assignment Modeling Using Augmentation Probabilities," Master's Thesis, Naval Postgraduate School, March 1996.

Smith, N.A., "Performance Measure Analysis of Command and Control Organizational and Task Structures," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: C2 measures of effectiveness, C2 technology, C2 evaluation, command, control and communications analysis techniques

APPLICATION OF MODERN COMPUTERS, INTERACTIVE ARRAY PROCESSING LANGUAGES, AND GRAPHICS TO TEACHING AND RESEARCH
W.G. Kemple, Assistant Professor
Command, Control and Communications Academic Group
P.A.W. Lewis, Distinguished Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: To develop a methodology for using interactive array processing languages and graphics such as S-Plus and APL2/AGSS to allow analysts to rapidly and interactively produce the kinds of analysis previously obtained with the FORTRAN program SIMTBED, and to produce vastly superior graphics for analysis.

SUMMARY: Some new features for statistical illustration that are useful for both teaching and analysis have been developed. One example is the nine-plot which had its genesis in the data analysis class. A basic normal probability nine-plot was developed to help determine whether the departures from straightness in a normal probability plot were extreme enough to reject the assumption of normality. The normal nine-plot placed the normal probability plot under investigation in the center of an array and surrounded it with eight similar probability plots, the difference being that in the eight surrounding plots, the data was generated (simulated) under the null hypothesis. If the departures from straightness in the center are more severe than in the surrounding plots, then the null hypothesis is in question. This idea was generalized to many data analysis situations and put into a paper.

OTHER:

Kemple, W.G., and Lewis, P.A.W., "Statistical Illustration Using Nine-Plots and Interactive Array Processing Languages," submitted to Journal of Computational and Graphical Statistics, June, 1996.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Normal probability plots, statistical illustration, statistical simulation, statistical visualization

GLIM FOR APPROXIMATE ESTIMATION OF RATE FUNCTIONS IN NON-HOMOGENEOUS POISSON PROCESSES
W.G. Kemple, Assistant Professor
Command, Control and Communications Academic Group
P.A.W. Lewis, Distinguished Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: To investigate simple ways of using GLIM for approximate estimation of rate functions in non-homogeneous poisson processes and for simulation of processes similar to those that produced the historical data being analyzed.

SUMMARY: Three concepts to use for the general specification of the model have been developed and APL2/AGSS and S-Plus functions have been written to fit alternative models under each of these concepts to the data. Alternative criteria for assessing the quality of the fit have been researched.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: GLIM, non-homogeneous poisson processes, statistical simulation

JOINT COMMAND, CONTROL AND COMMUNICATIONS CHAIR PROFESSOR
O.E. Marvel, Visiting Associate Professor
Command, Control and Communications Academic Group
Sponsor: Defense Information Systems Agency

OBJECTIVE: The goal of the project was to teach the C3 Systems Engineering Course (CC4101), provide student seminars on Command and Control, develop and advise on theses, and support research in C4ISR.

SUMMARY: The field of Systems Engineering gets more attention as we try to build bigger and more complex systems and where successful military missions require systems of systems that can operate across service and coalition boundaries. These ideas have been instilled into the students through the CC4101 course and the very successful seminar series for 1996. This year's seminar series was highlighted by the number of senior officers of General and Admiral rank who came to present and discuss very complex issues that must be solved for the future for the U.S. to continue to maintain military dominance and peace through deterrence. The major outcome of this year's research was the successful proposal to the Naval Sea Systems Command for the Command Center of the Future project.

PUBLICATIONS:

Marvel, O.E., "The Use of Simulation in the Battle Management (Planning) of Fully Automated TMD," Proceedings of ICCRTS 96, Market Bosworth, U.K., 23-27 September 1996.

CONFERENCE PRESENTATIONS:

Marvel, O.E., "The Use of Simulation in the Battle Management (Planning) of Fully Automated TMD," ICCRTS 96, Market Bosworth, U.K., 24 September 1996.

THESES DIRECTED:

Brintzinghoffer, D., "Naval Theater Ballistic Missile Defense (TBMD) - Development of the Information Exchange Requirements," Master's Thesis, Naval Postgraduate School, 1996.

Caudle, J.T., "Tenets for Lean U.S. Army Project Management Offices," Master's Thesis, Naval Postgraduate School, 1996

Hansley, E., "An Analysis of the Army's Tactical Packet Network," Master's Thesis, Naval Postgraduate School, 1996

Ottilige, D., "System Architecture for the Army Special Operations Forces (ARSOF) Soldier System," Master's Thesis, Naval Postgraduate School, 1996

DOD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software, Sensors, Modeling and Simulation

KEYWORDS: C4I, command and control, systems engineering, object oriented

SPECIAL OPERATIONS/LOW INTENSITY CONFLICT (SO/LIC) CURRICULUM TEACHING AND RESEARCH SUPPORT
G. McCormick, Associate Professor
Command, Control and Communications Academic Group
Sponsor: Special Operations Command

OBJECTIVE: Provide instructional and research support to the students and faculty of the Special Operations Curriculum.

SUMMARY: The Special Operations Curriculum is designed to provide a focused course of study of the conflict spectrum below general conventional war. Graduates of this curriculum will possess a close knowledge of the broad range of factors involved in the planning and conduct of these forms of conflict and a detailed understanding of the role of special operations and related forces in U.S. foreign and defense policy. The curriculum examines the sources and dynamics of inter-state and intra-state conflict, the challenge these forms of conflict have posed and are likely to increasingly pose for U.S. security planning, the doctrinal and institutional evolution of the U.S. special operations community, the recent history of political violence and "small wars" in Latin America, Asia, and the Middle East, the history of irregular warfare, and contemporary perspectives on low intensity conflict resolution. These requirements are supported by a larger program of study which provides the graduate with a broad background in the areas of international affairs, comparative strategy, the technological revolution in military affairs, and analytical methods.

DoD KEY TECHNOLOGY AREAS: Other (SO/LIC)

KEYWORDS: Conventional war, foreign policy, intra-state conflict, special operations, low intensity conflict

THE COMMAND AND CONTROL OF UNDERGROUND ORGANIZATIONS
G. McCormick, Associate Professor
Command, Control and Communications Academic Group
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: The purpose of this research is to examine the functions, methods, and structures of "underground" systems of command and control. Historical cases are also examined.

SUMMARY: Like other organizations, those operating in an underground or clandestine environment are designed, more or less effectively, to coordinate the individual actions of a collective membership. The process, mechanisms, and procedures created to carry out this task constitute their system of command and control. While the underground organization's need to operate clandestinely does not change the underlying principles of organizing, it does require significant changes in the ways in which effective and secure organization and internal coordination are achieved. Part one of this analysis presents a simple model delineating the command and control problems and tradeoffs that confront

secret organizations operating in a high threat environment. The second part of this analysis goes on to develop a typology identifying the alternative types of structures that have evolved to manage the underground command and control problem. Part three of this analysis examines the unusually important role played by informal or "unobtrusive controls" in underground command and control. In the final part of this analysis we examine how changes in an underground organization's environment will tend to result in changes in the constraints that shape its command structure and, hence, changes in its optimal command and control design. The analysis draws upon a wide range of current and historical cases for illustration.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Clandestine environment, command and control

TARGETING UNDERGROUND ORGANIZATIONS
G. McCormick, Associate Professor
Command, Control and Communications Academic Group
G. Owen, Professor
Department of Mathematics
Sponsor: Assistant Secretary of Defense and Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: This project has two objectives: 1) develop a formal framework for evaluating the dynamics of sub-state conflict, and 2) use this framework to examine the ways in which we might improve our ability to target terrorist organizations.

SUMMARY: The focus of this research project reflects the changing nature of the international conflict environment, which is now being increasingly defined by the proliferation of locally driven, ethnic, communal, and political wars. The high likelihood that the United States will continue to be drawn into such conflicts requires that we improve the analytical aids needed to evaluate, measure, and respond to such engagements effectively. This research project is designed to help satisfy this need by providing a series of interlocking studies examining the foundation and dynamics of sub-state conflict and the ways in which such dynamics can and cannot be controlled, contained, diffused, and deterred. Each study will identify and isolate the key factors and relationships that explain different parts of the larger sub-state conflict problem. Various control mechanisms available to the United States and other actors interested in shaping the outcome of such conflicts will be examined.

PUBLICATION:

McCormick, G., and Owen, G., "Revolutionary Origins and Conditional Mobilization," European Journal of Political Economy, Vol. 12, pp. 377-402, 1996.

DoD KEY TECHNOLOGY AREAS: Other

KEYWORDS: International conflict environment, sub-state conflict

GLOBAL BROADCAST SYSTEM TESTBED
P.H. Moose, Associate Professor
Department of Electrical and Computer Engineering and
Command, Control and Communications Academic Group
Sponsor: Naval Command Control and Ocean Surveillance Center

OBJECTIVE: The main goal of this project is to procure equipment to support the installation of a downlink testbed for the global broadcast system (GBS) in the NPS Systems Technology Laboratory (STL).

SUMMARY: During the final quarter of FY96, three satellite antennas with low noise blocks, a Cisco router, a low scan rate TV monitor, and miscellaneous cabling, and small parts were procured as commercial-off-the-shelf (COTS) equipment from a variety of suppliers and installed in Root Hall. The project is continuing in FY 1997, and additional equipment including a SPARC 20 Workstation and a KG-194 decryption device have been purchased and installed.

THESIS DIRECTED:

Carlisle, Robert S., "A Global Broadcast Service for the User on the Move," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: SATCOM, direct broadcast, wireless, communications

HDR COFDM MODEM
P.H. Moose, Associate Professor
Department of Electrical and Computer Engineering and
Command, Control and Communications Academic Group
Sponsor: Naval Command Control and Ocean Surveillance Center

OBJECTIVE: The objective of this project is to develop a MATLAB simulation of a COFDM modem and of maritime channel models at UHF for transmission of 1.5 Mbps in a 450 Khz bandwidth.

SUMMARY: During the final quarter of FY 96 and the first quarter of FY 97, an initial design for a COFDM modem using 212 carrier frequencies, 16-DPSK and RS error control coding and interleaving was prepared. MATLAB code was written to simulate the modem. Research was conducted at NRaD in San Diego to obtain required information to simulate the ship to ship, ship to air and ship to shore mobile maritime channels at UHF.

CONFERENCE PRESENTATION:

Moose, Paul H., "COFDM Modem Design for High Data Rate Wireless Communications," IEEE Signal Processing Society, San Diego, CA, 12 September 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: COFDM, high data rate digital communications, wireless, UHF

SYSTEMS ENGINEERING OF NETWORKED, DISTRIBUTED SYSTEMS
J.S. Osmundson, Associate Professor,
Command, Control and Communications Academic Group
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to develop analytical and modeling and simulation techniques for the analysis, design, rapid prototyping, and tradeoff studies of complex, time-critical, networked, distributed systems. The project was a two year effort beginning in January 1995, and ending in December 1996.

SUMMARY: In the past design and analysis of complex, time-critical networked, distributed information systems, including C^3 systems, has usually been done without extensive trade studies and without a good understanding of system sensitivities to design parameters and system input variations. Designs of new systems have often been based on previous architectures and existing technologies. Many instances of lack of C^3 systems capability trace to inadequate systems engineering and systems analysis during the systems conceptual and early development phases. In this

research project a technique was developed for graphically representing and computer modeling and simulating complex distributed systems. Models were developed and simulations run of the Navy's Cooperative Engagement Capability (CEC) and conventional joint air defense systems as these systems were deployed at the All Service Combat Identification Evaluation Team (ASCIET) exercises held in 1996. Results of simulations were compared to actual performance of the systems at ASCIET 96 in order to validate the modeling approach. Performance measures of the systems were then related to their architectural features.

PUBLICATION:

Osmundson, John S., "Comparison of CEC and Conventional Systems for Combat ID During ASCIET96," to be presented at the 1997 Joint Service Combat Identification Systems Conference, Naval Amphibious Base Coronado, San Diego, CA., 15-17 April 1996.

CONFERENCE PRESENTATIONS:

Huynh, Thomas V., and Osmundson, John S., "C2 Architecture for Joint Tactical Missile Defense (TMD)," 1996 Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Osmundson, J. S., Huynh, T.V., and Maiorana, J.M., "The Role of Modeling and Simulation in Requirements Analysis for Acquisition of C2 Software Systems," 1996 Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

THESES DIRECTED:

Brintzinghoffer, Daniel M., "Naval Theater Ballistic Missile Defense (TBMD) - Development of the Information Exchange Requirements," Master's Thesis, Naval Postgraduate School, June 1996.

Maiorana, Joseph M., "From Vision to Interoperability: An Analysis of Department of Defense and Service Initiatives," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Modeling and Simulation, Computing and Software, Battlespace Environments

KEYWORDS: Networking, systems engineering, systems analysis, distributed systems

JOURNAL PAPERS

Kemple, W.G., and Larson, H.J., "Computer Visualization of Battlefield Tenets," <u>Mathematical and Computer Modelling</u>, Vol. 23, No. 1/2, pp. 25-37, 1996.

Larson, H., Kemple. W., and Dryer, D.A., "Graphical Displays of Synchronization of Tactical Units" <u>Mathematical and Computer Modelling</u>, Vol. 23, No. 1/2, pp. 15-24, 1996.

Layne, C., "Less is More," <u>The National Interest</u>, Spring 1996.

McCormick, G.H. and Owen, G., "Revolutionary Origins and Conditional Mobilization," <u>European Journal of Political Economy</u>, Vol. 12, pp. 377-402, 1996.

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Boger, D.C., Adams, D.J., and Glass, T.H., "Information and C2 Effectiveness: An Experiment Using RESA," Proceedings of the 1996 Symposium on Command and Control Research and Technology, pp. 204-215. Naval Postgraduate School, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Kelly, R.T., and Morrison, J.G., "Decision Support for Tactical Decision Making under Stress," in Proceedings of the 1996 Symposium on Command and Control Research and Technology, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Morrison, J.G. and Kelly, R.T., "Principles for Aiding Complex Military Decision-making," in Proceedings of the 1996 Symposium on Command and Control Research and Technology, pp. 186-203, Monterey, CA, 25-28 June 1996.

Kelly, R.T., Hutchins, S.G., and Morrison, J.G., "Decision Processes and Team Communications with a Decision Support System," in Proceedings of the 1996 Command and Control Research and Technology Symposium, pp. 216-221, Monterey, CA, 25-28 June 1996.

Kelly, R.T., Hutchins, S.G., and Morrison, J. G., "Decision Processes and Team Communications with a Decision Support System," in Proceedings of the Second International Symposium on Command and Control Research and Technology, pp. 73-79, Market Bosworth, Warwickshire, U.K., 24-26 September 1996.

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Marvel, O.E., "The Use of Simulation in the Battle Management (Planning) of Fully Automated TMD," Proceedings of ICCRTS 96, Market Bosworth, U.K., 23 - 27 September 1996.

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CONFERENCE PRESENTATIONS

Beran, E., Porter, G., and Kemple, W., "Educating the Navy in C4I," 1996 Navy Research and Education Symposium on C4I, Annapolis, MD, 1996.

Boger, D.C., Adams, D.J., and Glass, T.H., "Information and C2 Effectiveness: An Experiment Using RESA," 1996 Symposium on Command and Control Research and Technology, Monterey, CA, 25 June 1996.

Hutchins, S.G., and Hutchins, R.G., "Decision Support for Enhancing Tactical Air Situation Awareness," First Annual Symposium on Situational Awareness in the Tactical Air Environment. Patuxent River, MD, 4-5 June 1996.

Hutchins, S.G., "Lessons Learned on Improving Decision Making under High Stress," TapRoot Incident/Accident Investigation Conference, Nashville, TN, 24-26 July 1996.

Hutchins, S.G., Kelly, R.T., and Morrison, J.G., "Decision Support for Tactical Decision Making under Stress," 1996 Symposium on Command and Control Research and Technology, pp. 204-215, Monterey, CA, 25-28 June 1996.

Hutchins, S.G., Morrison, J.G. and Kelly, R.T., "Development of a Decision Support System Based on Analysis of Operational Decisions," Military Operations Research Society, Ft. Leavenworth, KS, 18-20 June 1996.

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Kemple, W.G., Porter, G., and Vodantis, N., "Littoral Warfare Simulation Experiment," Command and Control Research and Technology Symposium, Monterey, CA, 1996.

Kleinman, D.L., Young, P.W., and Higgins, G., "The DDD-III: A Tool for Empirical Research in Adaptive Organizations," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Marvel, O.E., "The Use of Simulation in the Battle Management (Planning) of Fully Automated TMD," ICCRTS 96, Market Bosworth, U.K., 24 September 1996.

Moose, Paul H., "COFDM Modem Design for High Data Rate Wireless Communications," IEEE Signal Processing Society, San Diego, CA, 12 September 1996.

Morrison, J.G., Kelly, R.T., and Hutchins, S.G., "Impact of Naturalistic Decision Support on Tactical Situation Awareness," 40th Human Factors and Ergonomics Society Annual Meeting, Philadelphia, PA, 2-6 September 1996.

Osmundson, J.S., Huynh, T.V., and Maiorana, J.M., "The Role of Modeling and Simulation in Requirements Analysis for Acquisition of C2 Software Systems," 1996 Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Porter, G.R., "Joint Simulation Assessment," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

Sengupta, K., Berigan, M., Kleinman, D.L., and Serfaty, D., "Architectures for Command and Control Organizations: Dimensions of Task and Organizational Structure," Command and Control Research and Technology Symposium, Monterey, CA, 25-28 June 1996.

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Englund, C.E., Harris, W.C., Weinger, M.B., Feher, B.A., Hutchins, S.G., Callan, J.R., and Kelly, R.T., "Performance-shaping Factors (PSF): Considerations for Human Computer Interface (HCI) Design," in Advances in Applied Ergonomics, Ahmet Ozok and Gavriel Salvendy., eds., USA Publishing Corporation, West Lafayette, IN, 1996.

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Layne, C., "Congress is MIA in Bosnia Debate," Los Angeles Times, 7 January 1996.

OPERATIONAL ASSESSMENT OF SPACE BASED SITUATIONAL AWARENESS

Steven M. Arvanitas-Lieutenant, United States Navy
B.A., University of Utah, 1990
Master of Science in Systems Technology (Space Systems Operations)-September 1996
Advisor: Dan C. Boger, Command, Control, and Communications Academic Group
Second Reader: William Clifton, Space Systems Academic Group

Situational awareness is the comprehension of one's position at a given time and point in space. Space-based situational awareness is a concept that makes use of the Global Positioning System (GPS) to report the positions of all friendly units in a given area. This information is rapidly broadcast to all friendly units in order to prevent fratricide and enhance command and control. It can also assist pilots in maintaining aircraft separation. This capability can be installed on any platform irrespective of unit type (SEAL team, SH-60B, tank, etc.), service, or nationality making joint operations more effective.

This thesis explores the application and acquisition of space-based situational awareness for the U.S. military. It details the Situational Awareness Beacon with Replyh (SABER) system currently being fielded by the Space and Naval Warfare Systems ComEwadsworthmand. This system is currently an Advanced Concept Technology Demonstration (ACTD) program, and this assessment will focus on the overall operational concept of the prototype beacon system. Key features of the SABER system are detailed to give the reader an understanding of how situational awareness will be accomplished. An assessment of SABER's performance during an operational deployment with the 22nd Marine Expeditionary Unit and SABER integration issues in naval helicopters is also included.

INTEGRATION OF SPECIAL OPERATIONS AND CONVENTIONAL FORCES IN UNCONVENTIONAL WARFARE

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Master of Arts in National Security Affairs-March 1996
Advisor: John Arquilla, Information Warfare Academic Group
Second Reader: Gordon McCormick, Command, Control, and Communications Academic Group

Special operations forces (SOF) and conventional forces (hereafter referred to as general purpose forces or GPF) frequently operate together under a unified chain of command. When they do, conventional wisdom places GPF in command. In unconventional warfare operations, however, this subordination of SOF to GPF may hinder the ability of the integrated force to design and implement an appropriate solution.

This thesis examines the integration of SOF and GPF in unconventional warfare (UW) from an organizational perspective. It begins by examining the unique challenges posed by UW problems and establishing the organizational culture and functional specialization of SOF and GPF. It posits that SOF is, from an organizational perspective, better suited to designing solutions to UW problems than GPF. It further posits that by subordinating SOF to GPF the likelihood of the integrated force designing a campaign strategy appropriate for a UW problem is greatly reduced. It then uses the U.S. involvement in Vietnam to test these hypotheses. The thesis concludes that organizational factors do, in fact, play a role in the formation of strategy, and that careful consideration of the command relationships in future unconventional warfare operations is warranted.

TASK STRUCTURE AND SCENARIO DESIGN
Michael C. Berigan-Captain, United States Marine Corps
B. A., University of Florida, May 1989
Master of Science in Systems Technology-June 1996
Advisors: William G. Kemple, Command, Control, and Communications Academic Group
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The Adaptive Architectures for Command and Control (A2C2) project is a four-year effort sponsored by the Office of Naval Research to explore adaptation in command and control structures. The project's first experiment involves studying interaction between task structure and organization structure. Although the organization structure dimension of interest was clear, not enough was known of the dimensions of task structure to determine the dimension of interest without further study. This thesis describes a process for developing military operational scenarios within a task structure context. First, the author conducts a literature review, defines the dimensions of task structure applicable to this project, develops a grading scale for each dimension, gives examples of the dimensions and grades each example, and describes how changes in one dimension might affect other dimensions. Then a method for developing scenarios in accordance with a predetermined structure and visualizing tasks is described, including a task structure diagram and a description of a task design process using the diagram and the dimensions previously delineated. The author then applies the task design process by developing two scenarios for the first A2C2 experiment that differ across one dimension of task structure, *coordination requirements*. Finally, a description of the experiment is given, including discussion of operationalization of the scenarios and organization structures, and lessons learned from the experiment with regard to scenario design.

ANALYSIS OF DIGITAL CELLULAR STANDARDS
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Cellular communications has become one of the fastest growing segments in the telecommunications industry. The demand for cellular services has risen beyond all expectations. With the current growth of the analog cellular network, a strain has been put on the existing system and available spectrum. Cellular providers have been forced to use the existing bandwidth more efficiently by converting to digital technology. Four major digital cellular techniques are competing for marketplace dominance and each has the ability to expand the capacity of the cellular networks. The four systems are Global System for Mobile Communications (GSM), the Pan-European standard that utilizes FDMA/TDMA, using 25 MHz bandwidth channels, and operates in the radio frequency bands of 890-915 MHz for the uplink and 935-960 in the downlink; Digital Advanced Mobile Phone System (D-AMPS), the North American Digital Standard which is backwards compatible with the existing AMPS system; IS-95 manufactured by Qualcomm Inc. which utilizes the newest of the technologies CDMA, and finally Personal Digital Cellular (PDC), Japan's alternative which also uses TDMA technology. It is uncertain which system will become the standard, but it is certain that the ability to get to the marketplace, dominate it, and secure a stronghold in the market will be the successful standard.

NAVAL THEATER BALLISTIC MISSILE DEFENSE (TBMD) DEVELOPMENT OF THE INFORMATION EXCHANGE REQUIREMENTS

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As the United States moves into the next century one of the biggest threats facing her national interests is the proliferation of Theater Ballistic Missile (TBM) Systems, with their potential for carrying Weapons of Mass Destruction(WMD). In order for the United States to "project power", the Navy must play a large role in the protection of friendly assets from TBM attacks. Thus, the Navy is continuing to develop new systems and technologies as it attempts to migrate older weapons systems to fulfill this mission into its initial ballistic missile defense concept, Navy Area Defense (NAD). This thesis looks at the differences between the current "as is" physical/information architectures for the Anti-Air Warfare Commander and the future "to be" physical/information architectures for Theater Ballistic Missile Defense Commander.

The conventional anti-air warfare and TBM defense information requirements, on an Aegis, are developed using IDEF 0 Diagrams. These information requirement differences must be used as drivers for future system acquisition and development. Also, the potential problem areas associated with adding TBMD as an additional responsibility for the Air Warfare Commander (AWC) onboard and AEGIS platform, are covered.

The results of this thesis represent the initial plan (road map) for changes needed to support the evolving mission (Navy Area Defense) in the fleet.

DIPHONE-BASED SPEECH RECOGNITION USING NEURAL NETWORKS

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Speaker-independent automatic speech recognition (ASR) is a problem of long-standing interest to the Department of Defense. Unfortunately, existing systems are still too limited in capability for many military purposes. Most large-vocabulary systems use phonemes (individual speech sounds, including vowels and consonants) as recognition units. This research explores the use of diphones (pairings of phonemes) as recognition units. Diphones are acoustically easier to recognize because coarticulation effects between the diphone's phonemes become recognition features, rather than confounding variables as in phoneme recognition. Also, diphones carry more information than phonemes, giving the lexical analyzer two chances to detect every phoneme in the word. Research results confirm these theoretical advantages. In testing with 4490 speech samples from 163 speakers, 70.2% of 157 test diphones were correctly identified by one trained neural network. In the same tests, the correct diphone was one of the top three outputs 89.0% of the time. During word recognition tests, the correct word was detected 85% of the time in continuous speech. Of those detections, the correct diphone was ranked first 41.6% of the time and among the top six 74% of the time. In addition, new methods of pitch-based frequency normalization and network feedback-based time alignment are introduced. Both of these techniques improved recognition accuracy on male and female speech samples from all eight dialect regions in the U.S. In one test set, frequency normalization reduced errors by 34%. Similarly, feedback-based time alignment reduced another network's test set errors from 32.8% to 11.0%.

TENETS FOR LEAN U.S. ARMY PROJECT MANAGEMENT OFFICES

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Secretary of Defense William Perry directed DoD to develop a restructuring plan for the acquisition organization to accomplish a personnel reduction, reduce the acquisition process costs, and eliminate activities that are either unnecessary or not cost-effective. To this end, DoD and the Services initiated acquisition reforms aimed at changing the management and conduct of research, development and acquisition projects and more closely emulate world-class commercial companies' best practices. Objectives at the heart of these initiatives are to increase product quality and user satisfaction, decrease cycle times and costs, obtain predictable results, and reduce Government acquisition management overhead. This research examined the current state within the Army PMOs, the current environment in which Army PMOs operate, and the significant policies that influence the Army PMO organizational designs. The research examined world-class commercial corporations and military project management processes and the author interviewed project management personnel to identify the minimum core PMO processes and responsibilities, characterize opportunities that might meet the goals and objectives to obtain lean PMOs, and develop a supporting set of tenets. The results of this research can be used as a guide for the challenges faced in the ensuing organizational redesign efforts in the Army.

WIRELESS APPLICATIONS FOR MARINE AIR GROUND TASK FORCES

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Wireless telecommunications have a place in the Marine Corps' future. The challenge is finding ways to match Marine Corps needs with current and future digital wireless technologies. The advanced command and coordination concepts envisioned for future expeditionary operations mesh well with technologies explored in this study. These include cellular networks, wireless data networks, mobile satellite services, and personal communication services. Careful application of these technologies will improve Marine command and coordination efforts in dynamic environments. Instead of physical connections offering information exchange from place-to-place, wireless models offer true "person-to-person" information exchange, regardless of location. On the chaotic, unstructured battlefields of the next ten to twenty years, getting key information to specific people, as opposed to places, will be even more important than it is now. There are a number of Marine personnel, processes, and applications at the MAGTF that could benefit from commercially available wireless technologies.

ATTACKING THE INFRASTRUCTURE: EXPLORING POTENTIAL USES OF OFFENSIVE INFORMATION WARFARE

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The world has entered the Third Wave; it has entered the Information Age. One of the fundamentals of this paradigm shift is the fact that information is power. The side that controls information more effectively will be victorious. Thus, countries and militaries must change their mentality in order to survive. A new form of conflict, Information Warfare,

has been born. This new discipline is large, dynamic, and complex.

The need exists for education among military officers and other concerned professionals throughout the country. This thesis helps to bridge the education gap. It presents a snapshot of Information Warfare today, exploring many different avenues and possibilities along the way. The first half of the document is focused on Information Warfare in general, and the second half deals specifically with the offensive side.

The purpose of this thesis is not to present an all-encompassing view of Offensive Information War or even of Information Warfare in general. The field of Information Warfare is too big for any one individual or organization to fully comprehend all of its intricacies. Indeed, due to the dynamic nature of this discipline, chances are that some, or maybe even all, of the material contained herein will be obsolescent upon publication. The goal of the thesis is to present one view of Information Warfare, as seen through the eyes of many. The hope is that some benefit will be garnered by the reader, even if it only sparks an idea or helps to understand the importance of this growing warfare dimension.

OVERHEAD NON-IMAGING INFRA-RED (ONIR) SENSOR-TO-SHOOTER CONNECTIVITY OPTIONS FOR THEATER-WIDE BALLISTIC MISSILE DEFENSE AND PRE-APOGEE INTERCEPT FROM THE SEA

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This thesis studies dissemination of Overhead Non-Imaging Infra-Red (ONIR) Defense Support Program (DSP) and National System infra-red (IR) event and track data to tactical users. The study is motivated by a requirement to improve the lethality of Aegis class ships performing in a joint theater-wide ballistic missile defense (TBMD) role. The dissemination of IR data is considered within the context of the entire Theater Event System (TES) architecture and the combat system detect-control-engage TBMD cycle (expanded to sensor-processing-dissemination-weapons systems). Options that will improve the timely receipt of missile warning messages are reviewed. Potential future modifications to the TES architecture are examined in terms of their ability to pass IR missile warning messages to the tactical user within theater-wide missile defense requirements. Options reviewed include (1) early detect reporting, (2) tactical processing improvements, (3) Joint Tactical Ground Station (JTAGS) Remote(JTAGS-R) and (4) JTAGS Navy (JTAGS-N). A Measure of Performance (MOP) Baseline Standard is derived and the options presented are examined and evaluated against this MOP. Finally, based on this information feasibility analysis, a recommendation is made regarding future decisions and requirements for a sea-based theater-wide missile defense information architecture.

LEATHERNET: AN EVALUATION AS A MISSION PLANNING AND BRIEFING TOOL

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The author evaluates LeatherNet, a Distributed Interactive Simulation compliant, virtual simulation system being developed by the Advanced Research Projects Agency to demonstrate Modeling and Simulation (M&S) technologies and to partially fulfill the U.S. Marine Corps M&S goals. The research focuses on evaluation of LeatherNet as a mission planning and briefing tool for Marine infantry company commanders, staff, and subordinate leaders. Evaluation is

based on user perception and user performance on a live fire range subsequent to using the system. The user surveys indicate high user acceptance and belief that LeatherNet is a valuable mission planning and briefing tool and that LeatherNet has a good potential to be an effective training tool for commanders and their staffs. User performance, evaluated by subject matter experts on a live fire range, showed no statistically significant improvement for groups exposed to LeatherNet when compared to groups that did not use LeatherNet. The author explains why true differences, even if they do exist, would be difficult to detect due to the lack of experimental control and recommends action to be taken by the Marine Corps to conduct further testing with greater experimental control. The author also suggests steps the Marine Corps can take to optimize its investment in M&S.

AN ANALYSIS OF THE ARMY'S TACTICAL PACKET NETWORK

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This thesis represents an analysis of the U.S. Army's Tactical Communications System with particular emphasis on the Tactical Packet Network (TPN). It is a study of the Army's TPN and the proposed upgrade solutions. The U.S. Army awarded GTE a contract to replace the TPN Exterior Gateway Protocol with the Border Gateway Protocol. Additionally, the U.S. Army intends to upgrade the bandwidth of the Small Extension Node Switch and the Node Center Switch. The goal of both upgrades is to enhance the TPN.

One cannot look at TPN without looking at the overall infrastructure or the Army Tactical Command and Control System (ATCCS). Even this view is shortsighted. The ATCCS continues to evolve to meet the information requirements of the warfighter. Thus, a fair study must include our current capabilities and our future intentions for C4I. This thesis analyzes both.

AN ANALYSIS OF COMMERCIAL LOW EARTH ORBIT AND MEDIUM EARTH ORBIT MOBILE SATELLITE SYSTEMS AND THEIR POTENTIAL FOR MILITARY USE

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In recent years the United States military has been employed in more and more non-traditional roles as well as maintaining the ability to respond to crises throughout the entire spectrum of conflict. These missions can range from assisting civilian authorities providing disaster relief to responding to a major regional contingency. Often times these operations take place in remote or war torn regions of the world with little or no communications infrastructure. Additionally, today's emphasis on rapid deployment and maneuver warfare has resulted in our surpassing the capabilities of current military communications equipment. Expensive military satellite programs as well as the decline in defense spending has shifted our focus to more cost effective means of satisfying these requirements. Commercial mobile satellite systems (MSSs) such as Motorola's Iridium, Loral/Qualcomm's Globalstar, and TRW's Odyssey offer a possible solution. This thesis analyzes these three commercial MSSs, expected to have initial operational capabilities before the turn of the century, and their ability to satisfy current and anticipated DoD operational requirements. Each of these systems is examined in terms of their capabilities, vulnerabilities, and cost. Based on this analysis, a determination is made as to their potential for military use.

THE WARFIGHTERS' FUTURE LINK TO INFORMATION
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The purpose of this thesis is to introduce the concept of having a jointly integrated networking schema to better enhance battlefield communications and the dissemination of information using a smart push/pull concept from the highest commander down to the individual soldier. The concept of having a robust and dynamic network could provide the United States Armed Forces a better way of integrating the individual soldier's performance into higher level units. Current systems in the armed forces inventory are not truly interoperable, and not everyone has the capability to receive the information that these systems carry. A networked battlefield would allow everyone on the network to receive data carried by all systems.

With smart integration and design using commercially tested standards, the network can be built for all battlefield components. Each component would bring its equipment into the battlefield and become part of the network. Their systems would be able to plug and play with all other systems in the battlefield. The liberal use of COTS and GOTS networking equipment will reduce the cost of the network and would ensure compatibility among the battlefield components. Using OSI layers in the design of the system would ensure compatibility. DoD would need to make a concerted effort by having all of the services agree to make the battlefield network a top priority.

SATELLITE ON-ORBIT REFUELING: A COST EFFECTIVENESS ANALYSIS
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With the ever-shrinking military budget constraints facing military and civilian contractors, the ability to extend the operational life of any system for minimal cost compared to a replacement is desirable. This fact has never been more true than in today's space industry. This thesis addresses the possibility of extending satellite life through the use of on-orbit refueling. Through compilation and analysis of satellite operational life span data, it is shown that maneuvering fuel depletion has a significant impact on satellite operations in geosychronous orbit. If these satellites could be refueled economically this would prove not only cost-effective but also improve satellite tactical employment for space support to the warfighter. Through the manipulation of satellite data, launch/design costs, on-orbit refueling vehicle design/construction costs, and on-orbit operational requirements, it can be shown that on-orbit refueling can be done cost effectively. Single versus multiple satellite refueling operations were evaluated to determine the concept's viability.

THE DDD-III: A RESEARCH PARADIGM FOR ABSTRACTING JOINT C3 SCENARIOS FOR TIER-1 EXPERIMENTS
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Advances in communications technology and computers have made possible tremendous leaps forward in real-time Command and Control (C2). This revolution in C2 capability will provide decision makers (DMs) in the Joint military organization with an unparalleled tactical and strategic picture of the battlefield ("Global Awareness"). The ways in

which DMs having Global Awareness coordinate their information, resources and activities to fulfill the organization's mission is the focus of the Adaptive Architectures for Command and Control (A2C2) project. In order to examine these command and control issues empirically, the A2C2 project required a multi-player real-time simulation environment. A new computer model was needed to abstract "real world" problems into a controlled laboratory environment. The result was the Distributed Dynamic Decisionmaking (DDD-III) paradigm. The phase one experiment of the A2C2 project was designed to validate the 000-III paradigm, with emphasis on the manipulation of organizational variables. This document reviews the project objectives, 000-III capabilities, experiment one scenarios and scenario development issues. The scenario generator users guide and players tutorial, developed during phase one, are provided. The intent of this document is to link the phase one experiment to the next, more advanced phase of the A2C2 project.

INTEGRATED LOGISTICS SUPPORT IN SPECIAL OPERATION AVIATION— A CASE STUDY OF THE MH-60K AND MH-47E

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This thesis identifies the major factors faced by the Program Manager in developing and implementing the integrated logistics support plan (ILSP) for the U.S. Army's Special Operations Aircraft (SOA), the MH-60K and MH-47E. The SOA Program had many unique characteristics which made it a prime candidate for identification of major factors and development of lessons learned. Two of those unique characteristics are the facts that it was designated a nondevelopmental item (NDI) acquisition, and the fact that it is an extremely low density weapon system. Effective integrated logistics support (ILS) planning poses a challenge in "normal" developmental programs. Ensuring that ILS is handled effectively in low density NDI acquisitions can be a significantly more difficult challenge for the acquisition professional. This thesis develops a case study of ILS in the unique environment of the SOA Program. It also analyzes four maintenance specific ILS elements in an attempt to identify major factors that significantly impacted the development and implementation of the SOA ILSP. From these major factors, numerous lessons learned are developed. Some of the more important lessons learned are that: Sustainment of low density weapon systems is far more complicated and expensive through separate small Program Management Offices than it is through existing Program Management Offices; The density of the weapon system being procured is one of the most important factors to consider when making key ILS decisions; and Logistics Support Analysis tailoring and use are critical to establishing and implementing successful ILS in weapon systems. Study of the major factors and lessons learned presented in this thesis should improve the future development and implementation of ILSPs in Special Operations Aviation programs and NDI programs as a whole.

CASE ANALYSIS OF THE U.S. ARMY WARFIGHTING RAPID ACQUISITION PROGRAM: BRADLEY STINGER FIGHTING VEHICLE—ENHANCED WEAPONS SYSTEM

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The Army's Warfighting Rapid Acquisition Program (WRAP) transitions compelling U.S. Army Training and Doctrine Command Battle Lab experimentation successes into rapid acquisition successes. However, WRAP is not a "one-size-fits-all" material development solution to acquisition streamlining; it is best suited for programs relying on the integration of mature technologies which pose low technical risk, such as NDI.

This thesis analyzes the Bradley Stinger Fighting Vehicle-Enhanced (BSFV-E) air defense system to determine the impact of WRAP upon accelerated acquisition in this system's development. From this analysis of the BSFV-E pro-

gram as a single point of data, lessons learned are identified which might be used by other acquisition managers to effectively manage future programs which emerge as Battle Lab experimentation successes and are approved for rapid acquisition through the WRAP process.

One lesson learned is that BSFV-E's streamlined acquisition process permitted a significant reduction in the administrative and procedural requirements which typically burden systems development. In addition, this case study identified that lack of funding for WRAP-approved programs like the BSFV-E can potentially transform a rapid acquisition program into a business-as-usual program. This study concludes that the BSFV-E is one example of an excellent acquisition streamlining role model.

TRAINING DEVELOPMENT FOR NEW MATERIEL ITEMS IN ARMY ACQUISITION PROGRAMS

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This thesis was undertaken to analyze and document the Army's training development process as it relates to the materiel development of corresponding Army acquisition programs. Training development is a vital necessity for the successful fielding of any new materiel item. The acquisition process in general should not only focus on materiel development management, but on training development management as well. The performance of any weapon system will always be a measure of both how well the equipment is made and how well it is operated.

The study examines current Army doctrine and regulations, and it solicits input from various training development agencies to analyze the training development environment in this era of military reductions. The author's hypothesis was that the Army training development community is being reduced faster than materiel development programs. Interviews with training development personnel, and the results of a survey generated for this thesis support that hypothesis.

Given that training development reductions are outpacing materiel program elimination, the thesis provides two recommendations to reduce the negative impact on training development. One involves use of an automated document suspense management system to increase the efficiency of reduced staffs in training development agencies, the other outlines a potential methodology for procuring contractor provided training development.

A COMPARATIVE STUDY OF SYSTEMIC AND DOMESTIC FACTORS AFFECTING NATO ENLARGEMENT TO CENTRAL EUROPE

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NATO enlargement is the most contentious issue affecting the European security environment. Given that it is likely to occur, it is the responsibility of policy analysts and leaders to consider both the expected benefits for and the possible consequences of enlargement on the overall security environment. To do this, policy makers must have the tools to explore all aspects of the issue. This study attempts to provide three such tools.

First, case studies provide a view of some of the systemic and state level factors affecting the debate in Russia, the Czech Republic, Hungary, Poland, Slovakia, and the United States. Second, the study pits contending theories of these levels of analysis against each other to see if one does a better job of explaining/predicting state behavior. Finally, the study gives an overview of several policy implications of enlargement, including: how security guarantees will be

extended to new members; possible Russian reactions to enlargement; and, strategies for enlargement to ameliorate the expected adverse reaction of the Russians. How NATO expands will directly influence how the Russians react.

OBJECT ORIENTED DESIGN OF TACTICAL TIC-TAC-TOE C4I SIMULATION

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The purpose of this thesis is to redesign the Tactical Tic-Tac-Toe (T4) game using object-oriented design. T4 is a C4I simulation developed by Professor Gary Porter that is based on the traditional Tic-Tac-Toe game. It allows players to play against other players or against the computer. Various board sizes, multi-board games, delayed intelligence, team play, and limited communications are used to model real world C4I problems. The game allows for data collection for later analysis of game configurations and results. The goal of this thesis is to redesign the original program written in Macintosh HyperTalk language by using the Booch object-oriented design method and the C++ programming language for porting the program to a Unix or Windows environment with the ultimate goal of having a networked game that can be played remotely using a WWW browser type interface.

This design used requirements analysis and domain analysis to create class, operation, and attribute definition. Class association, aggregation, and inheritance are also specified. This design is ready to begin control class definition, access control definition, and operation algorithm development in preparation for coding an executable release.

FROM VISION TO INTEROPERABILITY: AN ANALYSIS OF DEPARTMENT OF DEFENSE AND SERVICE INITIATIVES

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This paper is an assessment of Department of Defense (DoD) and service initiatives to ensure joint interoperability of Command, Control, Communications, Computers, and Intelligence (C4I) systems. Using a consolidated initiative matrix, visions and actions are reviewed to identify intent, and existing documents used by C4I system planners, designers, and developers are assessed against essential system development criteria and required baseline actions to achieve interoperability. Findings reveal that interoperability development guidance and tools do not address mission-specific parameters of C4I systems. Not all C4I systems are the same. Mission-specific requirements dictate whether a system is interoperable or not. The current interoperability definition is quite vague for mission-specific systems, and existing DoD and service initiatives only address general guidance to focus system development. Common mission-specific cases are provided and demonstrate that achieving interoperability is more than general guidance and more than the ability to pass data or information through seamless interfaces to ensure that systems are functional. Interoperability must be further defined by analyzing a C4I system's unique mission. Finally, to guide C4I system design, a framework to establish quantifiable thresholds is developed and presented using existing joint doctrine.

THE MAE UAV: A ROLE IN THEATER MISSILE DEFENSE ATTACK OPERATIONS

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The changing nature of modern warfare and the rapid proliferation of theater ballistic missiles throughout the world have created a need for the development of operational concepts which address countering current theater missile (TM) threats. Destruction or disruption of an enemy's ability to successfully launch theater missiles will depend highly upon a near-real time intelligence dissemination process. Unmanned Aerial Vehicles (UAVs) may possess capabilities that allow them to assist counter-TM efforts as part of that process.

The thrust of this thesis is to draw conclusions regarding the Predator UAV's ability to assist counter-TM efforts in attack operations. The primary focus is locating and facilitating the destruction of mobile TM launchers through rapid dissemination of imagery to appropriate targeting systems. An historical discussion of U.S. theater missile defense (TMD) efforts and the use of UAVs in modern warfare is followed by a detailed description of the Predator system and a discussion of its vulnerability to exploitation. Finally, conclusions concerning Predator's ability to assist in such operations are made. Conclusions are based upon a wide range of exercise and demonstration documents that characterize Predator's operational performance.

A STOCHASTIC ENHANCEMENT TO THE ANALYST'S WORKBENCH

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The Analyst's WorkBench is a deterministic integrated framework developed and used by the Weapons Planning Group at NAWC China Lake. The model has no stochastic capability which requires all analysis to be conducted using parameters based on expected values of occurrence. This thesis develops a stochastic enhancement that can be incorporated in the Analyst's WorkBench. Independent identically distributed (IID) events can be generated by calls to the enhancement as a parametric input. To demonstrate the application of a stochastic process within the Analyst's WorkBench, a test scenario of a ship defense model is developed. A large scale missile attack is simulated deterministically and stochastically to demonstrate the differences of a random probability of successful defense vice an expected value of success. It is shown that the stochastic results provide a more realistic simulation and that the deterministic results overstate the capability of a system subject to random events that can be described by a statistical distribution.

INTERNATIONAL TECHNOLOGY TRANSFER: A CASE ANALYSIS OF THE MULTIPLE LAUNCH ROCKET SYSTEM AND THE PATRIOT MISSILE SYSTEM

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Acquisition strategies incorporating international cooperation have been gaining favor in DoD's weapon system procurements over the past ten years. This strategy is used to reduce life-cycle costs, improve global equipment interoperability, and foster international political unity. A by-product of international cooperation is normally some form of technology transfer between the countries involved in the cooperative effort. The purpose of this thesis is to identify and analyze the U.S. Project Office's role in enacting international technology transfers. This thesis focused on

two successful cooperative projects: the Multiple Launch Rocket System and the PATRIOT Missile System. Both weapon system acquisitions provided valuable insights into the complexities which surround international technology transfers. The principal findings are that clear and concise planning, coupled with an understanding of the U.S. licensing and transfer system, are critical to successfully executing a given transfer. Three primary recommendations are that: PM's identify "transfer-smart" personnel early in the process; once identified, those personnel be trained on both the intricacies of the transfer process and its influencers; and that the PM act as a political buffer, aggressively addressing the many issues that will surface during an international technology transfer.

CASE STUDY: AN EXAMINATION OF THE ROLE OF THE PROJECT MANAGER DURING THE FOREIGN MILITARY SALE OF THE MULTIPLE LAUNCH ROCKET SYSTEM TO ISRAEL

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The role of leadership in the international community has taken on a new meaning for the United States in the post Cold-War Era. American engagement and leadership are just as important today as they were during the Cold-War Era because we confront an interdependent world in which the line between our concerns at home and our interests abroad is increasingly blurred. The United States offers Security Assistance to strengthen the national security of friendly nations, support existing or prospective democratic institutions, and market-oriented economies. In some instances, we can leverage our power and resources through alliances and multinational institutions. We have a stake in helping our allies to strengthen their own defenses so that they can share the common defense burden. Even in times of shrinking domestic defense budgets, and a "downsizing" defense industrial base, the U.S. will continue to be the world leader in the transfer of defense articles and services to meet our foreign policy objectives. An examination of the role of the Project Manager is critical to increasing the efficiency of the Foreign Military Sales process. The functional management role of the Project Manager is vital to the success of FMS transactions. By closely examining the FMS case of the MLRS to Israel, we can further develop and refine the FMS process. Adoption of the recommendations of this thesis will help to improve project management and support future FMS transactions.

INTERNETWORKING: TECHNICAL STRATEGY FOR IMPLEMENTING THE NEXT GENERATION INTERNET PROTOCOL (IPV6) IN THE MARINE CORPS TACTICAL DATA NETWORK

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The Marine Corps must architect a tactical internet based on a software technology that is in transition–the Internet Protocol (IP). Development of the Marine Corps' tactical internetworking system (Tactical Data Network or TDN) is progressing concurrently with the global Internet community's development of the Next Generation Internet Protocol (IPv6). Current (IPv4) and next generation (IPv6) versions of the Internet Protocol can together meet the tactical internetworking needs of the Marine Corps.

IPv4 provides universal interoperability with other networking technologies and support for a wide range of services now, but without enhancements IPv4 cannot meet the long-terms needs of evolving tactical applications. IPv6 is needed to meet emerging requirements (such as secure mobility) but is not yet ready for implementation in the Tactical Data Network. Therefore the Marine Corps must build the tactical internet architecture using IPv4 and incorporate IPv6 improvements when transition is possible.

Marine Corps commitment to IP is essential to ensure universal interoperability and hardware-independent evolution of tactical applications and networking technology. This work presents a tactical IP addressing plan for TDN that

works with IPv4 and also facilitates smooth transition to IPv6. In concert with the other military services, the Marine Corps must develop a strategy for migrating the joint tactical internet to IPv6. The future viability of the Tactical Data Network depends on the Internet Protocol.

MATRIX ORGANIZATIONAL STRUCTURE AND ITS EFFECT ON ARMY ACQUISITION PROGRAM MANAGEMENT OFFICES

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With the implementation of the Defense Management Review, and publications of DoD Directive 5000.1 and DoD 5000.2-R, the Army was mandated to restructure program offices and operating procedures with the intent of cutting waste and fraud within the defense acquisition process. The goal was to establish an organizational structure which could operate efficiently in an environment of shrinking budgets and increasing technical specialization To address this challenge, the Army followed the aerospace industry's lead, and adopted the matrix management structure. Since its implementation, the matrix structure remains the management structure of choice within acquisition program offices throughout the Army.

While the structure has remained effective, its efficiency remains a point of contention with many program managers. This thesis focuses on evaluating the strengths and weaknesses of the matrix structure within acquisition program offices. In addition, the comments of 18 program managers will be offered regarding some possible methods and organizational variants which can be used to improve the matrix structure within acquisition program offices.

SYSTEM ARCHITECTURE FOR THE ARMY SPECIAL OPERATIONS FORCES (ARSOF) SOLDIER SYSTEM

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Keith F. Snider, Department of Systems Management

This thesis is based on proposing a system architecture for the Army Special Operations Forces (ARSOF) soldier. This system architecture will be based on object orientation and include Quality of Life (QOL) and Base Operations (BASOPS) programs integrated into the system architecture. The primary focus for this thesis is to propose a method or architecture to portray the ARSOF soldier as a system so that it can adequately compete against other weapon systems. The second reason is to identify and prioritize those functions and material which have an effect on the soldier and his mission accomplishment. It is a concern that the ARSOF soldier is being left out of the acquisition process because it is not perceived as a weapon system. This leaves the soldier vulnerable to inadequate funding which ultimately results in an ill-equipped and degraded capability for accomplishing present and future missions. USASOC wants to include not only material systems as part of the ARSOF soldier but also other intangible issues such as quality of life systems and base operations systems which have an effect on the ARSOF soldier's combat effectiveness. Army Special Operations requires specially trained soldiers and unique equipment that is not utilized by conventional forces. This system architecture will take special requirements into account. If the Army Special Operations soldier can be portrayed as a system, USASOC wants to determine how much of that system it has control or influence over, and how much it does not.

NEAR REAL TIME HUMAN INTELLIGENCE COMMUNICATIONS IN TIME CRITICAL TARGET EXPLOITATION

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The proliferation of weapons of mass destruction (WMDs) and the rapid pace of modern warfare has increased the need of the Joint Force Commander (JFC) to focus on time-critical targets (TCTs). Human intelligence (HUMINT) has had a long history of support to military targeting, but in recent years has often lacked the timeliness necessary to prosecute TCTs. Advanced communication technologies and innovative architectures are improving HUMINT's timeliness, and they promise to make HUMINT a much more valuable tool to the JFC.

The objective of this thesis is to provide an understanding of the capabilities and limitations of HUMINT in a tactical environment, and to show how, through the application of modern technology and proper organization, HUMINT can be made as responsive, if not more so, than national technical means of collection.

EMBEDDED SOFTWARE DEVELOPMENT: A CASE ANALYSIS OF THE U.S. ARMY BRADLEY FIGHTING VEHICLE A3 PROGRAM

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Embedded-software development is firmly established as a major cost, schedule, and performance risk in modern weapon systems programs. While embedded-software gives modern weapon systems enormous capability, the software acquisition process itself is undergoing a difficult evolution. This process is complicated by several factors: the complex demands placed upon software by modern, real-time weapon systems, the intangible nature of software, the software-as-art approach to development, and a general lack of software management expertise in many programs. The embedded-software development challenge becomes even greater when a traditional, hardware-oriented prime contractor, with no significant software experience, is selected to develop and integrate extensive software upgrades to existing weapon systems. The Bradley Fighting Vehicle A3 Upgrade (Bradley A3) Program provides valuable insight into the embedded-software product while simultaneously creating a software development process (where none existed previously) is extraordinarily difficult. When such a situation exists, program managers (PMs) must plan and schedule for the developer's learning curve. PMs must also assess their own levels of software development knowledge, educate themselves on software acquisition management, and seek assistance from sources which possess the requisite software acquisition expertise.

FUTURE INTELLIGENCE DISSEMINATION ARCHITECTURE

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Joint task force commanders rely on intelligence to provide insight into an uncertain world. To fill this need, there are several Department of Defense (DoD) mechanisms to gather and display a wide variety of information. For Signals Intelligence (SIGINT) dissemination there are three primary systems: the TRAP Data Dissemination System (TDDS) operated by the Navy, the Tactical Information Broadcast Service (TIBS) operated by the Air Force, and the Tactical

Reconnaissance Intelligence Exchange System (TRIXS) operated by the Army. In the Intelligence Authorization Act for Fiscal Year 1996, the House Select Committee on Intelligence threatened to freeze 75% of the DoD's intelligence budget until a comprehensive plan to unify intelligence broadcasts was completed. In response the Integrated Broadcast Service (IBS) plan was published by the Office of the Assistant Secretary of Defense for C3I. This thesis addresses the proposed IBS migration plan, the challenges ahead for the IBS program, the requirements for an ideal intelligence dissemination architecture, provides an assessment of the IBS with respect to the ideal system and makes recommendations for future intelligence dissemination. Two appendices are included: an example of the use of optical links in space-based information networks and a catalog of the satellite constellations operated by the National Reconnaissance Office (NRO). This thesis concludes that all intelligence dissemination should be carried on a global dissemination network for complete support to the warfighter.

A COMPUTER NETWORK SIMULATION TUTORIAL FOR COMNET III

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The military is heavily reliant on the transfer of information among various networks in its day-to-day operations. With fewer defense dollars available for the development of new systems, the use of commercial-off-the-shelf (COTS) hardware to build military information networks is becoming commonplace. The critical nature of much of this information requires that knowledge of the performance characteristics of the networks through which this information travels be known. These characteristics allow network managers and designers to plan for future growth of the network, analyze network reliability, and plan for the construction of new networks.

One method to determine the performance characteristics of a network is through the use of modeling and simulation. COMNET III release 1.1n is a COTS network simulation application which may be used to model and simulate both local and wide area networks. This thesis provides a tutorial to explain the theory used in the application for the modeling and simulation of networks. Each chapter presents the theory of several objects which may be used in the application, states a network problem which is to be analyzed, provides step-by-step instructions to build a model to analyze the network problem, and presents the results of the network simulation.

INFORMATION WARFARE: IMPLICATIONS FOR FORGING THE TOOLS

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One part of the modern Revolution in Military Affairs (RMA) is the possibility of a new form of warfare—often called information warfare. Development of information warfare depends on technological advances, systems development and adaptation of operational approaches and organizational structures. This thesis assesses the implications of information warfare for the technology and systems development areas, with the underlying motivation of ensuring the military is postured to "win the information warfare RMA" through effective research, development and acquisition. This assessment takes place primarily through a "Delphi" process designed to generate discussion between selected information warfare experts about the impacts of information warfare. This thesis concludes that information warfare is largely dependent on commercial information technology. This dependence means the military should rely on the commercial sector for most technological advances and products—with government research funds focused on military-unique research areas. Use of commercial items, coupled with DoD standard architectures, may enable a decentralization of information warfare acquisition to the user level. Finally, this dependence means the acquisition system

should focus on architecture development, technology insertion, systems integration and on managing functions and services of systems—primarily through development of operational software to run on mostly commercial hardware.

ENHANCED FIBER OPTIC GUIDED MISSILE: A CASE ANALYSIS OF FORCE STRUCTURE ISSUES EFFECTING THE PROGRAM

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Force structure issues are common in the acquisition of new technologies. In some cases, such as the Enhanced Fiber Optic Guided Missile (EFOG-M), it has been a painstaking effort to come to any consensus on how this system should be used and what force structure should support it. The introduction of fiber optic technology to the modern battlefield promises to revolutionize current doctrine and address a new dimension of battle. Fiber optic technology may give tomorrow's military the ability to direct precision fires against non-line of sight (NLOS) targets. This thesis examines the force structure issues effecting the Enhanced Fiber Optic Guided Missile (EFOG-M) program. The major focus is to determine if the current proposed force structure is the optimal solution and if not, suggest possible alternative solutions. Two courses of action were examined, both advocated deploying the EFOG-M system in platoon organizations organic to the battalion. An analysis of the current threat, previous studies, and concepts promulgated by Force XXI have enabled this study to recommend that the Army consider changing its current plan of deploying the EFOG-M at brigade level and field the system at battalion level.

A TWO-CUBED EXPERIMENT TO EXAMINE THE EFFECTS OF INFORMATION COMPLETENESS, WORK LOAD, AND FAST PATROL BOAT COMMAND AND CONTROL IN THE LITTORALS UTILIZING THE WARGAME SIMULATION: *BATMAN & ROBIN*

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Fast Patrol Boats were considered a negligible threat when the U.S. Navy focused on blue water operations away from shore. Now that the Navy's focus has shifted to the littorals, where these ships patrol, the Fast Patrol Boat's potential as a credible adversary is gaining acceptance. Moreover, the threat may be greatly enhanced if Fast Patrol Boats employ Commercial Off-The-Shelf Command and Control equipment to coordinate their efforts. This paper presents the design and results of a wargaming experiment conducted with *Batman & Robin* at the Naval Postgraduate School to examine this issue.

The research question is how would U.S. Navy Surface Action Groups perform against Fast Patrol Boats equipped with Commercial Off-The-Shelf Command and Control equipment which enables these comparatively unsophisticated ships to conduct coordinated attacks. The experiment also looked at two other factors: Surface Action Group work load, which might exacerbate the offensive capability of Fast Patrol Boats conducting coordinated attacks with advanced Command and Control; and the quality of information our Surface Action Groups are provided which could likewise play a pivotal role in a confrontation or engagement.

A two-cubed factorial experiment was conducted to test seven hypotheses. Data were collected on ten performance measures for 128 trials total. Significant results were obtained for three factors and three interactions. Operational explanations are provided.

NAVY TACTICS, DOCTRINE, AND TRAINING REQUIREMENTS FOR LITTORAL WARFARE

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The White Papers "...From the Sea' and "Forward...From the Sea" have shifted the focus of U.S. maritime strategy from open-ocean (blue-water) operations to near land (littoral) operations. U.S. naval strength lies in the capability to conduct sustained operations on the high seas, but the littoral environment and the potential enemy which may be encountered there impose new demands on our naval forces. It is imprudent to assume that the U.S. Navy can transfer their open-ocean proficiency into the littoral unmodified. This thesis evaluates the U.S. Navy's ability to conduct operations within this environment through its Littoral Warfare tactics, doctrine, and training. Then corrective actions for building littoral tactics and doctrine are recommended. It is intended that the recommendations will initiate a tactical debate to better prepare U.S. naval forces for operations within littoral regions throughout the world.

THE HAE UAV AND DYNAMIC RETASKING BY TACTICAL COMMANDERS

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Advancing technology and the changing nature and tempo of modern warfare has created many challenges. Desert Storm reiterated the need for Near-Real Time (NRT) imagery of the battlefield. History shows that Unmanned Aerial Vehicles (UAV) have the capability to meet some of these challenges. The Defense Airborne Reconnaissance Office (DARO) is directing a program to develop a family of UAVs that will meet the future NRT imagery needs of operational commanders. The High Altitude Endurance (HAE) UAV is part of this family of UAVs that will serve to provide sustained, broad area coverage for those commanders with time critical needs.

The thrust of this thesis is to define a process by which the time-critical Reconnaissance Surveillance and Target Acquisition (RSTA) imagery needs of the tactical commander on the battlefield can be met through effective dynamic retasking of the HAE UAV. This thesis examines HAE UAV capabilities, the intelligence cycle, and collection management procedures. Prohibitors of timely intelligence are highlighted. A process is described through which the HAE UAV may be dynamically retasked to meet the ground force commander's real-time collection requirements. The appropriateness of the HAE UAV to be used to satisfy the ground force commander's dynamic requirements is discussed.

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The Information Warfare Academic Group (IWAG) is an interdisciplinary group of faculty who hold appointments in various departments at the Naval Postgraduate School. These faculty members are responsible for guidance of the Electronic Warfare Curriculum for U.S. and International students. Their participation in the IWAG is voluntary and is a result of their interest in applying expertise to problems related to electronic combat.

Most IWAG faculty do some research related to electronic warfare. The primary purpose of this summary is to provide an overview of their work. In addition, there are a few faculty members who do IW research and who are not currently IWAG members.

The individual research summaries and publication lists of the IWAG faculty are not included in this section. Since all IWAG faculty hold appointments in their own department, their summaries and publications appear there.

During 1996, the membership of the Information Warfare Academic Group was as follows:

> Professor Frederic H. Levien (Electrical and Computer Engineering), Chair
> Commander Robert Young, USN, Curricular Officer
> Associate Professor Mike Bailey (Operations Research)
> Lieutenant Colonel Ernest K. Beran, USAF, Curricular Officer
> Assistant Professor Mitch Brown (National Security Affairs)
> Professor Alf Cooper (Physics)
> Professor Ken Davidson (Meteorology)
> Associate Professor Wayne Hughes (Operations Research)
> Associate Professor Dave Jenn (Electrical and Computer Engineering)
> Professor Jeff Knorr (Electrical and Computer Engineering)
> Professor Mike Morgan (Electrical and Computer Engineering)
> Associate Professor Phil Pace (Electrical and Computer Engineering)
> Professor Kurt Schleher (Information Warfare)
> Associate Professor Don Wadsworth (Electrical and Computer Engineering)

The following personnel, although not members of the 1996 IWAG, had research programs which contributed to the success of the electronic warfare program:

> Senior Lecturer Richard Adler (Electrical and Computer Engineering)
> Associate Professor Gurnam Gill (Electrical and Computer Engineering)
> Associate Professor Robert Hutchins (Electrical and Computer Engineering)
> Associate Professor Ramakrishna Janaswamy (Electrical and Computer Engineering)
> Professor Chin-Hwa Lee (Electrical and Computer Engineering)
> Associate Professor Ron Pieper (Electrical and Computer Engineering)
> Professor Clark Robertson (Electrical and Computer Engineering)

INDEPENDENT TECHNICAL ANALYSIS OF FLEET ANTI-SHIP CRUISE MISSILE TRAINING SIMULATOR
D.C. Schleher, Professor
Information Warfare Academic Group
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: Anti-shipping missiles are a major threat to ships, particularly in the littoral environment. The Fleet Organic at Sea Training System needs to be upgraded to reflect threats and requirements through the year 2020. Through independent analysis, identify a functional simulator system which satisfies U.S. Navy and Amphibious Ready groups' anti-ship cruise missile training requirement in the years 2000 to 2020.

SUMMARY: Under this research project, an independent technical analysis of an improved ALQ-170 simulator was conducted. The analysis resulted in the identification of a preferred system design capable of providing anti-ship cruise missile (ASCM) defense training through the years 2000 to 2020. The research used a system engineering approach to identify a preferred system design. A balanced set of requirements were determined on the basis of the Operational Requirement Document (ORD) and fleet messages. Measures of Effectiveness (MOE) and Measures of Performance (MOP) were determined from the requirements. A top level functional decomposition was performed to identify critical elements of the system. Four design alternatives were synthesized which range from a modification of the current design to a fully coherent, multi-polarization, broad band simulator with "dial-a-threat" capability. The various design alternatives were examined through a series of trade-off analysis studies. Preferred solutions for critical components of the transmitter, antenna, receiver and system characteristics were developed. A decision matrix method was used in the trade-off studies where weights were related to a prioritized set of system performance measures. A preferred solution was identified which used helix TWTs supported by a wide band quadridge multi-polarization horn fed reflector antenna.

THESIS DIRECTED:

Goldsmith, G.L., "System Analysis of New ASCM Simulator," Master's Thesis, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Anti-ship cruise missile, simulator, system engineering

INFORMATION WARFARE IN A JOINT WARFARE ENVIRONMENT
D.C. Schleher, Professor
Information Warfare Academic Group
Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: To develop a joint systems architecture which provides suppression of enemy command and control systems using information warfare techniques. This multi-year project first considers operation of the EA-6B, which has assumed a joint roll with the retirement of the EF-111A, and then replacement of the EA-6B by follow-on unmanned aerial vehicles.

SUMMARY: Under this research project, a number of issues pertaining to the effectiveness of current support jammers against modern radars were examined. It was determined that the current operational system has adequate capability against older type radar systems (e.g., the TPS-43E). However, when the TPS-43E is updated to a modern design (e.g., the TPS-70), the operational capability becomes marginal. The need for the support jammer to generate coherent or quasi-coherent jamming waveforms was established. The use of Direct Digital Synthesis (DDS) or Digital Radio Frequency Memory (DRFM) techniques for this purpose were compared and evaluated. It was found that the DDS required accurate frequency set-on beyond that available in the current operational system to provide adequate opera-

tional performance. The DRFM based system was shown to have adequate operational capability against modern radars, but performance degrades in a dense threat environment. A combined DDS/DRFM based system was developed which provided good performance in a dense threat environment against modern radars.

PUBLICATION:

Schleher, D.C., and Pace, P.E., "Comparison of Direct Digital Synthesis and RF Memory Exciter Techniques," Proceedings of the 41st Annual Joint Electronic Warfare Conference, Monterey, CA, May 1996.

CONFERENCE PRESENTATION:

Schleher, D.C., and Pace, P.E., "Comparison of Direct Digital Synthesis and RF Memory Exciter Techniques," Joint Electronic Warfare Conference, Monterey, CA, May 1996.

THESIS DIRECTED:

Watson, J., "A Comparison of DDS and DRFM Techniques in the Generation of 'Smart Noise' Jamming Waveforms," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

KEYWORDS: Support jamming, direct digital synthesis, digital RF memory

SIGNAL PROCESSING FOR WIDE AREA SURVEILLANCE
D.C. Schleher, Professor
Information Warfare Academic Group
Sponsor: U.S. Air Force-Rome Laboratory

OBJECTIVE: The goal of this project is to identify signal processing techniques for use in wide area surveillance radar. This research focuses on false alarm regulation in non-Gaussian clutter using adaptive CFAR techniques.

SUMMARY: This research developed an adaptive CFAR technique for use against non-Gaussian clutter, which provides false alarm regulation independent of the interferences probability distribution. The technique described is an adaptation of the log-t CFAR which is shown to be highly sensitive to the inclusion of small amounts of receiver noise in addition to the Weibull clutter for which it is tuned. An adaptive log-t CFAR is described which, under certain conditions, provides an order of magnitude better false alarm control than the conventional log-t CFAR. In addition, a Mellin transform technique is described which provides a false alarm regulation test. It is appropriate for many situations which employ standard probability models for radar clutter (i.e., Rayleigh, Weibull, Log-normal, K-distribution). This method also provides the probability density function of the CFAR test statistic in situations where the inverse Mellin transform is available.

The performance of a distribution-free CFAR in K-distributed clutter was also investigated. Limitations in its design were determined and a method was developed to simulate K-distributed clutter.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

KEYWORDS: Radar detection, CFAR, non-Gaussian clutter

CONFERENCE PAPERS

Schleher, D.C., and Pace, P.E., "Comparison of Direct Digital Synthesis and RF Memory Exciter Techniques," Proceedings of the 41st Annual Joint Electronic Warfare Conference, Monterey, CA, May 1996.

CONFERENCE PRESENTATIONS

Schleher, D.C., and Pace, P.E., "Comparison of Direct Digital Synthesis and RF Memory Exciter Techniques," Joint Electronic Warfare Conference, Monterey, CA, May 1996.

TECHNICAL REPORTS

Schleher, D.C., "Independent Technical Analysis of Fleet ASCM Training Simulator," Naval Postgraduate School, NPS-EC-96-021, December 1996.

Schleher, D.C., "Signal Processing for Wide Area Surveillance," Naval Postgraduate School, NPS-IW-10, December 1996.

INTEGRATION OF SPECIAL OPERATIONS AND CONVENTIONAL FORCES IN UNCONVENTIONAL WARFARE

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B.A., University of California, Santa Barbara, 1986
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Special operations forces (SOF)and conventional forces (hereafter referred to as general purpose forces or GPF) frequently operate together under a unified chain of command. When they do, conventional wisdom places GPF in command. In unconventional warfare operations, however, this subordination of SOF to GPF may hinder the ability of the integrated force to design and implement an appropriate solution.

This thesis examines the integration of SOF and GPF in unconventional warfare (UW) from an organizational perspective. It begins by examining the unique challenges posed by UW problems and establishing the organizational culture and functional specialization of SOF and GPF. It posits that SOF is, from an organizational perspective, better suited to designing solutions to UW problems than GPF. It further posits that by subordinating SOF to GPF the likelihood of the integrated force designing a campaign strategy appropriate for a UW problem is greatly reduced. It then uses the U.S. involvement in Vietnam to test these hypotheses. The thesis concludes that organizational factors do, in fact, play a role in the formation of strategy, and that careful consideration of the command relationships in future unconventional warfare operations is warranted.

INTERMODULATION IN CHANNELIZED DIGITAL ESM RECEIVER

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This thesis investigates intermodulation distortion generated by analog-to-digital converters (ADCs) in a channelized digital ESM receiver when processing multiple signals simultaneously. Spurious free dynamic range (SFDR) associated with this distortion is discussed. Two methods for increasing spurious free dynamic range are evaluated. First, by adding a small amount of Gaussian noise to the input of the receiver, the intermodulation distortion is found to be reduced significantly. Second, by using a narrow bandwidth sub-Nyquist sampling rate with high dynamic range ADCs it is possible to increase the spurious free dynamic range of the digital receiver. The first method is a simple approach but the ability to increase the SFDR is limited. The second method is more effective but requires greater computation and complex receiver design.

WHEN THE WEAK CHALLENGE THE STRONG THE NORTH KOREAN NUCLEAR CRISIS

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This thesis examines the political behavior of weak states in crises through a detailed case study of the recent North Korean nuclear crisis. In the early 1990s, North Korea initiated a political challenge that threatened both U.S. nonproliferation and South Korean defense interests. North Korea manipulated the shared risks of the ensuing crisis to achieve political objectives rather than military victory, which was unobtainable due to U.S. and South Korean defense efforts. It is puzzling how a small state, such as North Korea, could nevertheless successfully challenge more powerful states and not be punished. Indeed, North Korea was rewarded for its challenge. Asymmetric conflict theory states that a

weaker state, even after assessing its disadvantages vis-a-vis an opponent, can successfully challenge stronger adversaries to political and strategic advantage. In the North Korean nuclear crisis, its limited aims/fait accompli strategy—namely, developing nuclear weapons and gaining economic benefits from the West—and changing domestic politics were the driving force behind its challenge. The findings of this study provide some theoretical insights as well as policy implications for the United States and South Korea in their policy toward North Korean nuclear behavior.

A STUDY ON THE EFFECTS OF THROTTLE CHANGES AND FLARE DECOYS IN AN ENGAGEMENT BETWEEN THE F-14B/D TOMCAT AND THE AA-11 ARCHER IR AAM

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Technological advances coupled with extensive proliferation of infrared (IR) guided Surface-to-Air (SAM) and Air-to-Air (AAM) missiles arguably make them the most dangerous threat faced by tactical aircrews. The U. S. Navy has addressed this threat through aggressive IR countermeasures (IRCM) programs. One such program is the Electronic Warfare Advanced Technology (EWAT) Program sponsored by the CNO (N88). The Naval Postgraduate School and the EWAT Program are working together using modeling and simulation programs to evaluate proposed IRCMs.

This thesis uses the Modeling System for Advanced Investigation of Countermeasures (MOSAIC) software to simulate engagements between the Soviet-made AA-11 Archer IR AAM and the F-14B/D. Two scenarios, preemptive and defensive, are explored in which the F-14 uses flare decoys and/or reduction in power setting as recommended by the Navy Fighter Weapons School in an attempt to defeat the missile. A power modulation tactic, proposed by the Naval Air Warfare Center, Weapons Division, China Lake, is also examined. The results of the simulations are evaluated to determine the effectiveness of both current and proposed IRCM tactics.

ELECTRONIC ATTACK VULNERABILITIES OF AN ANALOG CELLULAR COMMUNICATION STANDARD

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Telecommunications is one of the fastest growing industries worldwide and cellular communications is one of the fastest growing sectors within telecommunications. Cellular mobile radio systems are now present in over 150 countries worldwide. These communications systems will be used to varying degrees in every future conflict in which the United States becomes involved. In many less affluent countries throughout the world cellular communications will become a defacto portion of those countries' civilian and military Command and Control (C2) infrastructure. Information Warfare (IW) planners must, therefore, determine vulnerabilities of cellular mobile radio systems that may be used by hostile forces. This thesis presents an examination, as well as experimental verification and modeling, of electronic attack techniques that could be used against an existing analog cellular communication standard.

COUNTERBATTERY DETECTION AND LOCATION FROM THE SEA USING THE AN/SPY-1 RADAR SYSTEM

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With a reawakening in littoral operations, there has been an increasing emphasis in revitalizing the U. S. Navy's Naval Surface Fire Support (NSFS) capability. This has primarily centered around improvements to weapon systems, but it must also include the other elements of a fire support system including target acquisition. One of the most successful systems in the ground battlefield environment, as evidenced by actions during Operation Desert Storm, has been the U. S. Army and Marine Corps Firefinder radars which can detect and locate firing positions of enemy indirect fire weapons so that enemy batteries can be quickly engaged. NSFS must substitute for the full spectrum of the ground fire support system until it can emplace ashore and then should augment it once it is ashore. Operations and contingencies of the last 15 years have demonstrated the need for a seamless capability of fire support, including target acquisition and especially counterbattery detection and location, across the complex sea-land interface. The AEGIS AN/SPY-1 radar, on cruisers and destroyers, has a similar phased array radar as the Firefinder system, which is the key to its success. This thesis looks at how the various models of this radar could be modified to perform the counterbattery mission with special emphasis on the problem of land clutter. The radar's integration into the entire amphibious force's fire support command and control network and the requirements for any future radar system are also addressed.

BEYOND SURPRISE: A CYBERNETIC APPROACH TO SPECIAL OPERATIONS

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Special operations, which generally employ small units against numerically superior forces, are exceptionally vulnerable to the frictions of war. Because the success of special operations is often of critical political or strategic importance, their degree of dependability must be as high as possible. Toward that end, this study develops a cybernetic approach to special operations. The central element of this study is the delineation of a "cybernetic advantage," which amounts to a relative differential in the speed, accuracy and effectiveness of implementation of decisions made by opposing commanders, and the efficiency of conversion of combat potential to combat power.

Surprise is an important element in the conduct of all types of warfare and is generally considered to be critical to the success of special operations. Yet history is replete with examples of special operations that have been successful without surprise. The cybernetic approach, which draws from the classic theory of control through feedback, provides an explanation for the success of these operations. Additionally, the model based on this theory attempts to operationalize the tenets of the cybernetic approach in a manner that can be utilized as a tool for planning and analysis.

This study proposes that a small force can achieve and maintain relative superiority as long as a cybernetic advantage is maintained. Furthermore, the study proposes that the cybernetic approach, when employed in conjunction with other principles of special operations, can act as a force multiplier. This approach can, in theory, be employed to some degree by any size force at any level of warfare. However, special operations forces are especially suited for the use of this tool.

INTERCEPTING A COVERT NAVAL RADAR
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Radars with low probability of intercept (LPI) characteristics present a considerable threat to current electronic support measures (ESM) receivers. A radar with LPI characteristics could conceivably track a target without ever being detected. The Pilot class of marine radars has just such a claim. Developed in 1986, the Pilot class of covert radars are being sold on the world market by Celsiustech as the *Pilot Mk 2* and by Signaal as the *Scout*. The Pilot class of radar uses a frequency modulated continuous wave (FMCW) carrier and very low power to remain virtually undetectable while painting targets as far as 25 miles away. This thesis assesses the LPI threat and describes how the Pilot radar is rapidly emerging as a new class of LPI radars. It tests the Pilot's claim of "indetectability" by evaluating the Pilot waveform against the ALR-81(V)3, one of the U.S. Navy's most sensitive and versatile Electronic Intelligence (ELINT) receivers. Designed and built by Condor Systems, the ALR-8 1(V)3 scanning superheterodyne receiver is part of the electronic warfare (EW) suite aboard the ES-3A Sea Shadow reconnaissance plane. A test conducted in cooperation with Condor Systems demonstrated the performance of the actual ALR-8 1 (V)3 receiver hardware verses a simulated Pilot radar waveform.

INFORMATION AGE TERRORISM: TOWARD CYBERTERROR
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The growing ubiquity of computers and their associated networks is propelling the world into the information age. Computers may revolutionize terrorism in the same manner that they have revolutionized everyday life.

Terrorism in the information age will consist of conventional terrorism, in which classic weapons (explosives, guns, etc.) will be used to destroy property and kill victims in the physical world; technoterrorism, in which classic weapons will be used to destroy infrastructure targets and cause a disruption in cyberspace, and cyberterrorism, where new weapons (malicious software, electromagnetic and microwave weapons) will operate to destroy data in cyberspace to cause a disruption in the physical world.

The advent of cyberterrorism may force a shift in the definition of terrorism to include both disruption and violence in cyberspace in the same manner as physical destruction and violence. Through the use of new technology, terrorist groups may have fewer members, yet still have a global reach. The increasing power of computers may lower the threshold of state sponsor ship to a point where poor states can become sponsors and rich states are no longer necessary.

This thesis explores the shift toward information warfare across the conflict spectrum and its implications for terrorism. By examining the similarities and differences with past conventional terrorism, policy makers will be able to place information age terrorism into a known framework and begin to address the problem.

THE VULNERABILITY OF AN AIRBORNE EARLY WARNING (AEW)
SYSTEM AGAINST STAND-OFF NOISE JAMMING (SOJ)

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Based on the lessons learned from the Falkland War, an airborne early warning (AEW) system's importance is fully appreciated, and many countries field the AEW system to be a force multiplier for their air defense system. In this thesis, the AEW system's vulnerability, the sensitivity of each factor dominating the AEW system's detection range under hostile jamming, and the effect of stand-off noise jamming (SOJ) impacting the AEW system's detection range are evaluated using a simulation model to explore the AEW system's susceptibility and detection range degradation in a realistic combat environment.

SOF AND CONVENTIONAL FORCE INTEROPERABILITY THROUGH SOF RECONFIGURATION

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Master of Arts in National Security Affairs-March 1996
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Gordon McCormick, Information Warfare Academic Group

The goal of this thesis was to decide what environment variables affected past SOF attempts at achieving interoperability with the conventional military, to examine the status of SOF and conventional forces interoperability as it exists today, and to explain why now is the time for SOF to engage in the reconfiguration of its forces to achieve an optimal level of interoperability.

Five variables were used in the examination of SOF organization evolution toward interoperability with conventional forces. The interplay of these variables showed that environment changes combined with sponsorship of civilian leadership had a dominant, yet, short-lived effect on SOF attempts at achieving interoperability with the conventional military, and that the incremental gains in structural and organizational aspects of SOF created conditions for achieving interoperability in the future. This window of opportunity is temporary, since SOF exists in an environment of competitive bureaucracies. Recommendations for SOF leaders in their pursuit of interoperability with conventional forces are presented. An opinion on how SOF might reconfigure itself to engage interoperability is provided.

A STUDY OF UHF FLTSATCOM VULNERABILITIES AND ITS APPLICATION
TO CLASSIC CRYSTAL

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Master of Science in System Engineering-September 1996
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Second Reader: D. C. Schleher, Information Warfare Academic Group

Determine the minimum satellite transponder uplink frequency separation for satellites having overlapping field-of-views for the world-wide UHF FLTSATCOM system (LEASAT/GAPFILLER/FLTSAT/UFO) for the current satellite orbit configuration/ transponder frequency plan. Examine the vulnerability of the SSIXS users given the current UHF satellite system configuration/frequency plan and see if a more intelligent choice of channel/frequency plan could reduce the vulnerability of SSIXS DAMA users.

TIMELY AND RELEVANT IW/C²W MODELING
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Today's environment is characterized by rapid technological change in communication systems and networks. These rapid changes make the task of developing timely and useful C²W and C²W support systems difficult at best. This thesis provides discussion on whether commercial-off-the-shelf programs, combined with government-off-the-shelf models, can create solutions to the IW/C²W challenge. We worked with a modeling and simulation program, GLEEM, developed by the AFIWC to analyze GPS links in an hostile jamming environment. Here, GLEEM is considered a starting point for a generic modeling program to be used for detailed analysis of C²W related network links. We chose GLEEM because it includes features not completely included in other projects, thus providing a greater capability to model real world IW scenarios and questions posed by commanders. Two means of providing insight on GLEEM are used. First, we use GLEEM to simulate a modern mobile communication link and the ability of a space-based receiver to detect the signal. Second, we use the information we've learned about GLEEM to discuss how it might be used to simulate current research at NPS. We conclude that programs like GLEEM are in their infancy but there is significant potential and development work should continue.

BISTATIC RADAR CROSS SECTION SYNTHESIS FOR RECTANGULAR RESISTIVE SHEETS
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A method of moments solution for the bistatic scattering from planar resistive sheets is presented. The matrix scattering equations are inverted to obtain a rigorous inverse solution that can be applied to the synthesis of radar cross section. Computer calculations for several sheets demonstrate that the synthesized resistivity is in good agreement with the original resistivity.

EFFECTIVENESS OF OFF-BOARD ACTIVE DECOYS AGAINST ANTI-SHIPPING MISSILES
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Radar guided anti-shipping missiles are the primary threat for most modern Navies. The inherent nature of the monopulse radar employed by most anti-shipping missiles makes it highly resistant to active ECM techniques. Decoys are attractive because they provide a source of radiation that can capture the radar seeker and direct the missile away from the ship. However the time and direction of launch are critical parameters which determine the operational success of the decoy.

This thesis evaluates the protection provided by active off-board decoys which are deployed by ships during an engagement against a radar guided anti-shipping missile. The research emphasizes launching active decoys. Many of the operational characteristics of the launching decoy are investigated, including direction of launch, timing of launch and the RF characteristics of the decoy.

A COMPARISON OF DDS AND DRFM TECHNIQUES IN THE GENERATION OF "SMART NOISE" JAMMING WAVEFORMS

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This thesis presents a comparison of the effectiveness of "smart noise" jamming waveforms against advanced threat radars, which are generated using either Direct Digital Synthesis (DDS) or Digital RF Memory (DRFM) based support jamming. The challenge lies in the fact the modern radar employs advanced waveforms, ultra-low sidelobe antennas, coherent sidelobe cancelers, and sidelobe blankers to inhibit signals entering through its sidelobes. This thesis compares the effectiveness of using DDS versus DRFM techniques to meet this challenge. In particular, the effect of mismatched frequency on the DDS jamming waveform is described, as is the effect of quantization and multi-signal storage in the DRFM. A quantitative comparison of these jamming techniques against the AN/TPS-70 surveillance radar is made.

SPACE SYSTEMS
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The Space Systems Academic Group (SSAG) is an interdisciplinary association providing direction and guidance for the Space Systems Engineering and Space Systems Operations curricula. The SSAG relies on faculty and facilities support from the departments of Aeronautics and Astronautics, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Operations Research, Physics, and Systems Management. The SSAG also benefits from the support of four Academic Space Chairs: Navy TENCAP Space Chair, Naval Space Technology Program Chair, Navy Space Systems Academic Chair, and Michael J. Smith Space Systems Chair.

The mission of the SSAG is threefold. The SSAG designs the curricula to provide a firm foundation in the broad array of disciplines which comprise the focus for Space Systems Engineering and Space Systems Operations. The SSAG also directs space research at NPS, thereby promoting practical learning opportunities through both theoretical and hardware-based thesis research. The third role of the SSAG is to ensure that officer students in the Space Systems Curricula receive practical experience through experience tours. A six-week experience tour is taken by each officer student hosted by any of a number of facilities from industry, Federal Government, or other universities.

Marrying the academic goals of the SSAG with the practical application of space technology for defense needs, the ongoing small satellite project provides an environment ideal for students to gain experience in design, development, testing, system integration, and operations of spacecraft and payloads. Officer students are exposed to space related research topics as well as formal classroom instruction. Many officer students have chosen research topics directly related to the small satellite design studies program.

In the 1996 academic year, officer students in the Space Systems Curricula and participating faculty from several departments were involved with the Petite Amateur Navy Satellite (PANSAT) project.

1996 SSAG membership includes:

Professor Rudolf Panholzer (Electrical and Computer Engineering), Chair
Professor Brij Agrawal (Aeronautics and Astronautics)
Alan Ross (Space Systems), Navy TENCAP Space Chair
Chis Baldwin (Space Systems), Navy Space Systems Academic Chair
Tom Betterton (Space Systems), Naval Space Technology Program Chair
Professor Oscar Biblarz (Aeronautics and Astronautics)
Professor Dan Boger (Systems Management)
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Instructor Randy Wight (Electrical and Computer Engineering)
Commander Robert Young, USN, Curricula Officer

SMALL SATELLITE DESIGN STUDIES PROGRAM

Directed by Professor Rudolf Panholzer, the Small Satellite Design Studies Program is part of the Spacecraft Technology research effort incorporating proven and leading-edge technology in a space system development project. The Small Satellite Design Studies project continues in the development of the Petite Amateur Navy Satellite (PANSAT) space system. PANSAT is a small satellite being developed at NPS by officer students, faculty, and staff, for launch into a low-Earth orbit as a secondary payload via the Shuttle Hitchhiker program. Launch and integration is provided by the Department of Defense Space Test Program (STP).

PANSAT will provide digital communications using direct sequence spread spectrum using the amateur radio ultra-high frequency (UHF) band. Communications will be centered at 436.5 MHz with approximately 2.5 MHz of bandwidth. Transmission data rate will be 9.842 kbps using a 7-bit shift register with taps at 7 and 1 for the generation of the pseudonoise (PN) code. The second pre-space notification was filed by the FCC on behalf of NPS to the International Telecommunications Union on June 20, 1995 promulgating the PANSAT communications parameters. The time period for comments expired on May 30, 1996.

PANSAT will perform store-and-forward message relay, meaning messages received by the spacecraft will be stored on-board until they are commanded to be down-linked to the ground station. This is done autonomously by the spacecraft through its on-board processor and memory. Thorough testing of the electronics and software which controls the on-board processing is currently in progress to ensure a robust system. During the 1996 fiscal year, progress was made in hardware development, software development, mission operations, as well as issues related to flight opportunities and Shuttle integration.

Spacecraft Development

The PANSAT spacecraft consists of the digital control subsystem (DCS), electrical power subsystem (EPS), communications payload (COMM), and the mechanical structure. Progress was made in FY96 in all areas of hardware development. All subsystems have been prototyped and are currently undergoing testing for functionality and software control. Prototype electronics also have been integrated on the benchtop to investigate functionality and control algorithms by software. Specifically, a battery charge algorithm was developed using the prototype EPS, a prototype battery, temperature multiplexer, and temperature, voltage, and current measurements to arrive at a means of starting up the spacecraft once its separated from the Shuttle. This is probably the most crucial event, since the spacecraft will be operating entirely autonomously with a number of possible initial states. Additionally, the spacecraft must fall back on this battery charge algorithm in the event of a failure where the processor is reset.

In addition to the progress in electronics development, the spacecraft structure and mechanical systems have progressed to near completion. Flight component manufacturing was about 75% complete by the end of FY96, and the structure design was approximately 90% complete. Also, some environmental testing was performed for the battery cells. Random vibration testing of three nickel-cadmium (NiCd) battery cells were performed at Hitchhiker qualification levels, or 12.9 grms in the axial and lateral directions. This was necessary since the NiCd cells used for flight are commercial, off-the-shelf items. No appreciable change was noticed on the tested cells. The cells were returned to the vendor for further analysis.

Programmatic Developments

Other progress included an increase in dialogue between NPS, STP, and NASA during the FY96 period for an eventual Shuttle flight. Although PANSAT is not yet manifested on any Shuttle mission, progress is being made to facilitate PANSAT's flight opportunities. An initial technical interchange meeting (TIM) was held in April 1996 at NPS for the STP personnel. This was followed up with dialogue between NPS, STP, and NASA personnel, resulting in finalized payload requirements for PANSAT as a Shuttle secondary payload. Also, initial documentation was submitted to NASA (via STP) which is required for the NASA safety reviews, including the Safety Data Package, and associated hazard reports.

OPERATIONAL ASSESSMENT OF SPACE BASED SITUATIONAL AWARENESS

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Second Reader: William Clifton, Space Systems Academic Group

Situational awareness is the comprehension of one's position at a given time and point in space. Space-based situational awareness is a concept that makes use of the Global Positioning System (GPS) to report the positions of all friendly units in a given area. This information is rapidly broadcast to all friendly units in order to prevent fratricide and enhance command and control. It can also assist pilots in maintaining aircraft separation. This capability can be installed on any platform irrespective of unit type (SEAL team, SH-60B, tank, etc.), service, or nationality making joint operations more effective.

This thesis explores the application and acquisition of space-based situational awareness for the U.S. military. It details the Situational Awareness Beacon with Reply (SABER) system currently being fielded by the Space and Naval Warfare Systems ComEwadsworthmand. This system is currently an Advanced Concept Technology Demonstration (ACTD) program, and this assessment will focus on the overall operational concept of the prototype beacon system. Key features of the SABER system are detailed to give the reader an understanding of how situational awareness will be accomplished. An assessment of SABER's performance during an operational deployment with the 22nd Marine Expeditionary Unit and SABER integration issues in naval helicopters is also included.

LAUNCH DETECTION SATELLITE SYSTEM ENGINEERING ERROR ANALYSIS

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An orbiting detector of infrared (IR) energy may be used to detect the rocket plumes generated by ballistic missiles during the powered segment of their trajectory. By measuring angular directions of the detections over several observations, the trajectory properties, launch location, and impact area may be estimated using a nonlinear least-squares iteration procedure. Observations from two or more sensors may be combined to form stereoscopic lines-of-sight (LOS), increasing the accuracy of the estimation algorithm. The focus of this research has been to develop a computer-model of an estimation algorithm, and determine what parameter, or combination of parameters will significantly affect on the error of the tactical parameter estimation. This model is coded in MATLAB, and generates observation data, and produces an estimate for time, position, and heading at launch, at burnout, and calculates an impact time and position. The effects of time errors, LOS measurement errors, and satellite position errors upon the estimation accuracy were then determined using analytical and Monte Carlo simulation techniques.

ES-3A EXPLOITATION OF NATIONAL RECONNAISSANCE ASSETS
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Integrating national and tactical intelligence systems is an important priority in our National Security Strategy. Until recently though, national and tactical sensors operated separately. National systems focused on strategic priorities with little thought given to the needs of warfighters. But as Desert Storm demonstrated, national and tactical reconnaissance platforms, operating jointly, are critical in providing threat warning and precision targeting. Operating individually, national and tactical platforms suffer various limitations. When integrated, a synergy is achieved allowing the full potential of each component to be realized. In accordance with this warfighting trend, the ES-3A tactical signals intelligence aircraft will soon be equipped with the capability to directly receive intelligence from national assets. Little thought has been given as to what this new capability implies, especially in terms of how it will change the way the ES-3A is employed. Therefore, this thesis will discuss the kinds of intelligence the ES-3A mission commander can expect to receive from national systems, how that data will be delivered to the aircraft, how it is fused with intelligence derived from on-board sensors, and finally how this fused product can be used to accomplish mission tasks.

ORBITAL DEBRIS: COST IMPACT ON SETTING POLICY
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As the exploration of space increases, the problems associated with orbital debris also increase. Orbital debris continues to grow at a linear rate with an ever increasing possibility of a shift to an exponential rate. If this point is achieved, space travel will, at best, be extremely hazardous and at worst, unusable. When mitigating orbital debris, cost and policy issues must be addressed. Currently, no policy exists that makes the mitigation of orbital debris mandatory but it only strongly recommends mitigation if it is cost effective. This thesis addresses the cost impact of alternative spacecraft design options for orbital debris mitigation. The cost impact is shown by developing generic satellite characteristics, considering two different altitudes, and using alternative design options.

UNDERSEA WARFARE ACADEMIC GROUP

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The Undersea Warfare Academic Group (USWAG) consists of eleven faculty members plus the Curricular Officer. The faculty members teach in the USW curriculum and are responsible for its academic content. Members conduct USW-related research and serve as thesis advisors for USW students.

Associate Professor Steve Baker (Physics)
Visiting Professor Al Bottoms (Undersea Warfare)
Professor Robert Bourke (Oceanography)
Assistant Professor Donald Brutzman (Undersea Warfare)
Associate Professor Ching-Sang Chiu (Oceanography)
Professor James Eagle (Operations Research), Chair
Associate Professor Ralph Hippenstiel (Electrical and Computer Engineering)
Assistant Professor Robert Keolian (Physics)
Professor James Sanders (Physics)
Associate Professor Clyde Scandrett (Mathematics)
Assistant professor Kevin Smith (Physics)
Professor Alan Washburn (Operations Research)
CDR Bob Young, Curriculum Officer

An overview of research sponsored by the Undersea Warfare Academic Group is provided below:

MIDDLE ATLANTIC BIGHT FIELD STUDY: Ching-Sang Chiu and Kevin Smith collaborated with Woods Hole Oceanographic Institute in the ONR-sponsored Middle Atlantic Bight Field Study. The overall goal is to understand the propagation of sound from the continental slope to the continental shelf, including the effects of shelf-break frontal features and seasonal stratification.

ACTIVE ACOUSTIC TRANSIENT LOCALIZATION: Kevin Smith and Ching-Sang Chiu investigated the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals. The eventual research goal is to develop effective and accurate methods for passive transient localization.

BARENTS SEA TOMOGRAPHY: Ching-Sang Chiu, James Miller and Robert Bourke continued the analysis of data obtained in the 1992 Barents Sea Polar Front Experiment.

OCEAN VARIABILITY: Ching-Sang Chiu, James Miller and A.J. Semtner studied the variability and stability of cross-basin acoustic arrivals using Hamiltonian ray tracing for selected source-receiver sites through various Semtner-Chervin global ocean model outputs.

MULTICAST BACKBONE (MBONE): Donald Brutzman configured a local area network at the Naval Undersea Warfare Center (NUWC)-Newport, to support real-time audio and video. Also demonstrated was the use of multicast audio/video services in support of the New Attack Submarine Open System Critical Item Test.

CAVES NOISE CANCELLATION: Robert Keolian and LCDR Daphne Kapolka developed a correlated noise cancellation technique for the CAVES fiber optic flank array. The output of noise sensors placed near internal noise sources are correlated with the output of the CAVES sensors to obtain running average transfer functions between the noise sources and the array. These accumulated transfer functions and the instantaneous noise signals are used to subtract the self-noise appearing in the CAVES sensors.

MINE COUNTERMEASURES PROGRAM: Don Walters investigated methods for the identification and classification of mine-like objects using adaptive acoustic imaging plus synthetic and inverse synthetic aperture sonars techniques. Al Bottoms occupied the Chair of Mine Warfare and provided overall coordination of mine warfare-related activities at NPS. This included planning the weekly Menneken Lecture Series on Mine Warfare and coordinating preparations for a major mine warfare symposium scheduled for November 1996 at NPS.

SHALLOW WATER BOTTOM REVERBERATION: Robert Bourke and James Wilson investigated the impact of bottom reverberation and energy spreading loss on AN/SQS-53C performance in shallow water.

NPS MOBILE COMPUTING AND COMMUNICATIONS RESEARCH GROUP
Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
MAJ J. Cummiskey, USMC
Department of Computer Science
Sponsor: U.S. Marine Corps Systems Command

OBJECTIVE: The purpose of the work described in this proposal is twofold. First, the interoperability of palmtop computers with the U.S. Marine Corps Data Automated Communications Terminal (DACT) to rapidly disseminate combat order message packets over wired and wireless channels will be researched. Second, the advantages of various wired and wireless transmission media will be investigated and evaluated, including radio frequency (RF), infrared (IR), point-to-point wire, Ethernet, and wireless local-area networks (LANs).

SUMMARY: The United States Marine Corps has begun to develop a system called the Digital Automated Communications Terminal (DACT). The DACT system is based around a sub-notebook-sized, tactical input/output battlefield situational awareness system and communications terminal. The problem is that DACT's excessive weight, size, cost and complexity might ultimately prevent its successful integration into the rapidly evolving Marine Corps style of maneuver warfare. This project provides a study of palmtop-sized mobile computing platforms to include the Hewlett-Packard family of palmtops, as well as the emerging Microsoft Pegasus mobile operating system. Furthermore, various messaging standards, protocols and commercial digital transmission channels are analyzed for their suitability to DACT requirements. Finally, a system prototype called the "Rapid Electronic Delivery of Messages over Asynchronous Networks" (REDMAN) is implemented to disseminate field orders under combat conditions. REDMAN speeds the flow of accurate information to all levels of command within a Marine infantry battalion using a commercial palmtop platform. This commercial palmtop is 3-7 times lighter and 20-30 times less expensive than DACT. Wireless networked palmtop computing will completely change the scope of Marine warfighting.

THESES DIRECTED:

Cummiskey, James, "Interoperability of Palmtop Computers with the U.S. Marine Corps Data Automated Communications Terminal (DACT) to Rapidly Disseminate Combat Order Message Packets over Wired and Wireless Channels," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://dubhe.cc.nps.navy.mil/~jccummis/

Nierle, James E., "Internetworking: Technical Strategy for Implementing the Next Generation Internet Protocol (IPv6) in the Marine Corps Tactical Data Network," Master's Thesis, June 1996. Available at http://www.stl.nps.navy.mil/~jenierle/thesis.html

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Mobile computing, wireless battlefield, palmtop, Tactical Data Network (TDN)

MAKING GOOD THE PROMISE: A REGIONAL INFRASTRUCTURE MODEL FOR SCIENCE EDUCATION BY WAY OF ELECTRONIC FIELD TRIPS
Kam Matray, Monterey Peninsula Unified School District (MPUSD)
Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Sponsors: National Science Foundation and Naval Postgraduate School

OBJECTIVE: Connect regional primary and secondary schools to the Internet for innovative teaching and distance learning in combination with regional environmental scientific research.

SUMMARY: A large number of Monterey Bay regional institutions are working together to establish and utilize Internet and World Wide Web connectivity. Goals include improving education access to information and enabling constructivist pedagogical approaches which tie innovative scientific research with school curricula. NPS provided technical expertise and assistance in establishing a sustainable wide-area network (WAN) in Monterey and Santa Cruz counties.

THESES DIRECTED:

Courtney, Dale Michael, "Internetworking: NPS ATM LAN," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.stl.nps.navy.mil/~iirg/courtney/

Dennis, Ronald Michael, "Internetworking: Integrating IP/ATM LAN/WAN Security," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.stl.nps.navy.mil/~iirg/dennis/

Edwards, Evan, "Internetworking: Automated Local and Global Network Monitoring," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.stl.nps.navy.mil/~iirg/edwards/

Erdogan, Ridvan, "Internetworking: Implementation of Multicasting and MBone over Frame Relay Networks," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.stl.nps.navy.mil/~iirg/erdogan/

Mihlon, Lauren, "Internetworking: Multicast Videoteleconferencing over ISDN, Master's Thesis," Naval Postgraduate School, September 1996.

Tamer, Murat, "Internetworking: Multicast and ATM Network Prerequisites for Distance Learning," Master's Thesis, June 1996. Available at http://www.stl.nps.navy.mil/~iirg/tamer/

Tiddy, Michael E., "Internetworking: Economical Storage and Retrieval of Digital Audio and Video for Distance Learning," Master's Thesis, June 1996. Available at http://www.stl.nps.navy.mil/~iirg/tiddy/

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Distance learning, multicast, MBONE, ATM, Frame Relay, video teleconferencing (VTC)

AUTONOMOUS UNDERWATER VEHICLE (AUV) DOCKING
Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: Solve open problems in underwater vehicle control to dock an AUV with a tube in the presence of time-varying turbulent flow fields.

SUMMARY: Algorithms for sensing, maneuvering and precise control relative to a docking station were developed and tested. The work is now on sensing and maneuverability in the presence of turbulent cross-body flow. This effort addresses a significant problem facing AUVs where success has broad implications. An ongoing dialog with researchers in the French Navy has proven productive.

PUBLICATIONS:

Brutzman, Don, Healey, Tony, Marco, Dave, and McGhee, Bob, "The Phoenix Autonomous Underwater Vehicle," AI-Based Mobile Robots, David Kortenkamp, Pete Bonasso and Robin Murphy, eds., MIT/AAAI Press, Cambridge MA, (accepted). Available at http://www.stl.nps.navy.mil/~auv/aimr.ps

Wheless, Glen H., Lascara, Cathy M., Valle-Levinson, Arnoldo, Brutzman, Donald P., Sherman, William, Hibbard, William L., and Paul, Brian E., "Virtual Chesapeake Bay: Interacting with a Coupled Physical/Biological Model," IEEE Computer Graphics and Applications, Vol. 16 No. 4, pp. 52-57, July 1996.

Wheless, Glen H., LaScara, Cathy M., Valle-Levison, Arnaldo, Brutzman, Donald P., Sherman, William, Hibbard, William L., and Paul, Brian E., "Chesapeake Bay Virtual Ecosystem Model (CBVEM): Initial Results from the Proto-typical System," International Journal of Supercomputer Applications, Sage Science Press, Vol. 10, No. 2/3, pp. 199-210, Summer/Fall 1996. Available at ftp://ftp.ccpo.odu.edu/pub/wheless/wheless_ijsa.tar

CONFERENCE PRESENTATION:

Brutzman, Don, "Tutorial: Virtual World for an Autonomous Underwater Vehicle (AUV)," IEEE Oceanic Engineering Society Conference AUV 96, Monterey CA, 3-6 June 1996. Available at http://www.stl.nps.navy.mil/~auv/uvw_tutorial.html

Brutzman, Don, Brauns, Bryan, Fleischman, Paul, Lesperance, Tony, Roth, Brian, and Young, Forrest, "Evaluation of AUV Search Tactics for Rapid Minefield Traversal Using Analytic Simulation and a Virtual World," Symposium on Technology and the Mine Problem, Mine Warfare Association, Monterey CA, 18-21 November 1996. Available at http://www.stl.nps.navy.mil/~auv/simulation/mcm96.ps with software and results available at http://www.stl.nps.navy.mil/~auv/simulation/

Brutzman, Don, Burns, Mike, Campbell, Mike, Davis, Duane, Healey, Tony, Holden, Mike, Leonhardt, Brad, Marco, Dave, McClarin, Dave, McGhee, Bob, and Whalen, Russ, "NPS Phoenix AUV Software Integration and In-water Testing," IEEE Oceanic Engineering Society Conference AUV 96, Monterey CA, 3-6 June 1996. Available at ftp://taurus.cs.nps.navy.mil/pub/auv/auv96.ps

THESES DIRECTED:

Burns, Michael, "Merging Virtual and Real Execution Level Software for the Phoenix Autonomous Underwater Vehicle," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.cs.nps.navy.mil/research/auv/thesispages/burns/abstract.html

Campbell, Michael Scott, "Real-time Sonar Classification for Autonomous Underwater Vehicles," Master's Thesis, Naval Postgraduate School, March 1996.

Davis, Duane Thomas, "Precision Maneuvering and Control of the Phoenix Autonomous Underwater Vehicle for Entering a Recovery Tube," Master's Thesis, Naval Postgraduate School, September 1996. Available at http://www.cs.nps.navy.mil/research/auv/thesispages/davis/abstract.html

Leonhardt, Bradley J., "Mission Planning and Mission Control Software for the Phoenix Autonomous Underwater Vehicle (AUV): Implementation and Experimental Study," Master's Thesis, Naval Postgraduate School, March 1996. Available at http://www.cs.nps.navy.mil/research/auv

OTHERS:

Brutzman, Donald P., and Whitfield, Martin, eds., Video Proceedings of the IEEE Oceanic Engineering Society (OES) OCEANS 96, Fort Lauderdale, FL, 23-26 September 1996.

Brutzman, Donald P., and Holden, Michael J., eds., Video Proceedings of the IEEE Oceanic Engineering Society (OES) Autonomous Underwater Vehicles 1996, Naval Postgraduate School, Monterey, CA, 3-6 June 1996. Program available at http://www.stl.nps.navy.mil/~auv/auv96_video.html

Healey, Tony, Marco, Dave, Brutzman, Don, and Davis, Duane, "Phoenix AUV In-Water Tests with Virtual World Design," Video Proceedings of the IEEE Oceanic Engineering Society 1996, Naval Postgraduate School, Monterey, CA, 3-6 June 1996. Program available at http://www.stl.nps.navy.mil/~auv/auv96_video.html#phoenix

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation, Sensors, Computing and Software

KEYWORDS: Autonomous Underwater Vehicle, robot, AUV, control, virtual worlds

RAPIDLY RECONFIGURABLE VIRTUAL ENVIRONMENT NETWORK PROTOCOLS
Mike Zyda, Professor
Department of Computer Science
Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: Create a formally specifiable behavior protocol that permits scalable inter-entity interactions to be defined, modified and tested while large-scale exercises are in progress.

SUMMARY: A Distributed Interactive Simulation (DIS) library was built in the Java language. Hooks to generic 3D scenes drawn using the Virtual Reality Modeling Language (VRML) are being creating . Completed thesis work shows how to formally specify protocol data unit (PDU) elements and subsequently autogenerate reader/writer source code. The new DIS library will be extended to permit on-the-fly modification in mid-exercise, permitting experimental optimization of behavior protocols and overcoming a key DIS deficiency. This functionality will be implemented as Area of Interest Manager (AOIM) applets or agents (i.e., mobile executable code) which consolidates multicast channel selection, subscription and desubscription of network streams, either for individual hosts or local-area networks (LANs).

PUBLICATIONS:

Stone, Steve, Zyda, Michael, Brutzman, Don, and Falby, John, "Mobile Agents and Smart Networks for Distributed Simulations," 14th DIS Workshop on Standards for the Interoperability of Distributed Simulations, Institute for Simulation and Training, Orlando FL, paper 96-14-133, pp. 909-917, 11-15 March 1996. Available at http://www-npsnet.cs.nps.navy.mil/npsnet/publications/Mobile.Agents.and.Smart.Networks.for.Distributed.Simulations.pdf

Brutzman, Don, Zyda, Mike, and Macedonia, Mike, "Cyberspace Backbone (CBone) Design Rationale," 15th DIS Workshop on Standards for the Interoperability of Distributed Simulations, Institute for Simulation and Training, Orlando FL, paper 96-15-99, 16-20 September 1996. Available at http://www.stl.nps.navy.mil/~brutzman/CBoneDIS.ps

Brutzman, Don, "Graphics Internetworking: Bottlenecks and Breakthroughs," chapter, Digital Illusions, Clark Dodsworth editor, Addison-Wesley, Reading Massachusetts, (accepted). Available at http://www.stl.ns.navy.mil/~brutzman/vrml/breakthroughs.html

THESIS DIRECTED:

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McGregor, Don, and Brutzman, Don, "Java-based Distributed Interactive Simulation (DIS) Library," February 1996. Available via http://www.stl.nps.navy.mil/~brutzman/java/#DialAProtocol and ttp://www.stl.nps.navy.mil/~brutzman/java/source_reference.html

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Large-scale virtual environments (LSVEs), network protocols, multicast, DIS

JOURNAL PAPERS

Wheless, Glen H., LaScara, Cathy M., Valle-Levison, Arnaldo, Brutzman, Donald P., Sherman, William, Hibbard, William L., and Paul, Brian E., "Chesapeake Bay Virtual Ecosystem Model (CBVEM): Initial Results from the Prototypical System," International Journal of Supercomputer Applications, Sage Science Press, Vol. 10, No. 2/3, Summer/Fall 1996, pp. 199-210. Available at ftp://ftp.ccpo.odu.edu/pub/wheless/wheless_ijsa.tar

Wheless, Glen H., Lascara, Cathy M., Valle-Levinson, Arnoldo, Brutzman, Donald P., Sherman, William, Hibbard, William L., and Paul, Brian E., "Virtual Chesapeake Bay: Interacting with a Coupled Physical/Biological Model," IEEE Computer Graphics and Applications, Vol. 16, No. 4, July 1996, pp. 52-57.

CONFERENCE PAPERS

Brutzman, Don, Zyda, Mike, and Macedonia, Mike, "Cyberspace Backbone (CBone) Design Rationale," 15th DIS Workshop on Standards for the Interoperability of Distributed Simulations, Institute for Simulation and Training, paper 96-15-99, Orlando FL, 16-20 September 1996. Available at http://www.stl.nps.navy.mil/~brutzman/CBoneDIS.ps

Stone, Steve, Zyda, Mike, Brutzman, Don, and Falby, John, "Mobile Agents and Smart Networks for Distributed Simulations," 14th DIS Workshop on Standards for the Interoperability of Distributed Simulations, Institute for Simulation and Training, paper 96-14-133, pp. 909-917, Orlando FL, 11-15 March 1996. Available at http://www-npsnet.cs.nps.navy.mil/npsnet/publications/Mobile.Agents.and.Smart.Networks.for.Distributed.Simulations.pdf

CONFERENCE PRESENTATIONS

Brutzman, Don, Brauns, Bryan, Fleischman, Paul, Lesperance, Tony, Roth, Brian, and Young, Forrest, "Evaluation of AUV Search Tactics for Rapid Minefield Traversal Using Analytic Simulation and a Virtual World," Symposium on Technology and the Mine Problem, Monterey CA, 18-21 November 1996. Available at http://www.stl.nps.navy.mil/~auv/simulation/mcm96.ps with software and results available at http://www.stl.nps.navy.mil/~auv/simulation/

Brutzman, Don, Burns, Mike, Campbell, Mike, Davis, Duane, Healey, Tony, Holden, Mike, Leonhardt, Brad, Marco, Dave, McClarin, Dave, McGhee, Bob, and Whalen, Russ, "NPS Phoenix AUV Software Integration and In-water Testing," IEEE Oceanic Engineering Society Conference AUV 96, Monterey CA, 3-6 June 1996. Available at ftp://taurus.cs.nps.navy.mil/pub/auv/auv96.ps

Brutzman, Don, "Tutorial: Virtual World for an Autonomous Underwater Vehicle (AUV)," IEEE Oceanic Engineering Society Conference AUV 96, Monterey CA, 3-6 June 1996. Available at http://www.stl.nps.navy.mil/~auv/uvw_tutorial.html

CONTRIBUTION TO BOOK

Brutzman, Don, "Graphics Internetworking: Bottlenecks and Breakthroughs," Digital Illusions, Clark Dodsworth ed., Addison-Wesley, Reading, MA, (accepted). Available at http://www.stl.ns.navy.mil/~brutzman/vrml/breakthroughs.html

OTHER

Brutzman, Donald P., and Holden, Michael J., eds., Video Proceedings of the IEEE Oceanic Engineering Society (OES) Autonomous Underwater Vehicles 1996, Naval Postgraduate School, Monterey California, June 3-6 1996. Program available at http://www.stl.nps.navy.mil/~auv/auv96_video.html

Brutzman, Donald P., and Whitfield, Martin, eds., Video Proceedings of the IEEE Oceanic Engineering Society (OES) OCEANS 96, Fort Lauderdale, FL, September 23-26, 1996.

Healey, Tony, Marco, Dave, Brutzman, Don and Davis, Duane, "Phoenix AUV In-Water Tests with Virtual World Design," Video Proceedings of the IEEE Oceanic Engineering Society 1996, Naval Postgraduate School, Monterey California, June 3-6 1996. Program available at http://www.stl.nps.navy.mil/~auv/auv96_video.html#phoenix

McGregor, Don, and Brutzman, Don, Java-based Distributed Interactive Simulation (DIS) Library, February 1996. Available via http://www.stl.nps.navy.mil/~brutzman/java/#DialAProtocol and http://www.stl.nps.navy.mil/~brutzman/java/source_reference.html

MERGING VIRTUAL AND REAL EXECUTION LEVEL CONTROL SOFTWARE
FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE
Michael L. Burns-Lieutenant, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Computer Science-September 1996
Advisors: Robert B. McGhee, Department of Computer Science
Don Brutzman, Undersea Warfare Academic Group

The Naval Postgraduate School (NPS) is developing an AUV, Phoenix. The Phoenix has the capability of precise navigation, however too much time is needed to validate a new section of code. NPS is also developing a virtual AUV, which has the capability of being networked, having flexible missions, and having a quick feedback of results when validating new portions of code. The virtual AUV has a drawback of never being tested for real world precision. This thesis discusses the steps taken to combine these two sets of control code to obtain the maximum functionality that will drive either the virtual or actual AUV and produce a faster feedback response to newly developed code.

As a result of this effort, the newly developed control code has successfully driven both the actual and virtual AUVs and provides a means for readily validating new code. Also this new control code has given the AUV research group the ability to perform distributed software development, test all AUV hardware from either the onboard or offboard computers, conduct flexible missions, and test missions in the virtual world prior to conducting them with the AUV.

REAL-TIME SONAR CLASSIFICATION FOR AUTONOMOUS UNDERWATER VEHICLES
Michael Scott Campbell-Lieutenant, United States Navy
B.S.E.E., Ohio Northern University, 1989
Master of Science in Computer Science-March 1996
Master of Science in Electrical Engineering-March 1996
Advisors: Don Brutzman, Undersea Warfare Academic Group
Xiaoping Yun, Department of Electrical and Computer Engineering

The Naval Postgraduate School autonomous underwater vehicle (AUV) Phoenix did not have any sonar classification capabilities and only a basic collision avoidance system. The Phoenix also did not have the capability of dynamically representing its environment for path planning purposes.

This thesis creates a sonar module that handles real-time object classification and enables collision avoidance at the Tactical level. The sonar module developed communicates directly with the available sonar and preprocesses raw data to a range/ bearing data pair. The module then processes the range/bearing data using parametric regression to form line segments. A polyhedron-building algorithm combines line segments to form objects and classifies them based on their attributes. When the Phoenix is transiting, the classifying algorithm detects collision threats and initiates collision avoidance procedures.

The result of this thesis is a fully implemented sonar module on the Phoenix. This module was tested in a virtual world, test tank and in the first ever sea-water testing of the Phoenix. The sonar module has demonstrated real-time sonar classification, run-time collision avoidance and the ability to dynamically update the representation of the unknown environment. The sonar module is a forked process written in the "C" language, functioning at the Tactical level. Source code and output from an actual Phoenix mission displaying the object classification of the sonar module are included.

INTERNETWORKING: THE INTEROPERABILITY OF COMMERCIAL MOBILE COMPUTERS WITH THE USMC DIGITAL AUTOMATED COMMUNICATIONS TERMINAL (DACT)

James C. Cummiskey-Major, United States Marine Corps
B.S., California State University, Dominguez Hills, 1987
Master of Science in Computer Science-September 1996
Advisor: Don Brutzman, Undersea Warfare Academic Group
Second Reader: Lou Stevens, Department of Computer Science

The United States Marine Corps has begun to develop a system called the Digital Automated Communications Terminal (DACT). The DACT system is based around a subnotebook-sized, tactical input/output battlefield situational awareness system and communications terminal. The problem is that DACT's excessive weight, size, cost and complexity might ultimately prevent its successful integration into the rapidly evolving Marine Corps style of maneuver warfare.

This thesis provides a study of palmtop-sized mobile computing platforms to include the Hewlett-Packard family of palmtops, as well as the emerging Microsoft® Pegasus mobile operating system. Furthermore, various messaging standards, protocols and commercial digital transmission channels are analyzed for their suitability to DACT requirements. Finally, a system prototype called the "Rapid Electronic Delivery of Messages over Asynchronous Networks" (REDMAN) is implemented to disseminate field orders under combat conditions. REDMAN speeds the flow of accurate information to all levels of command within a Marine infantry battalion using a commercial palmtop platform. This commercial palmtop is 3-7 times lighter and 20-30 times less expensive than DACT. Wireless networked palmtop computing will completely change the scope of Marine warfighting. This thesis provides a proof of concept system that demonstrates such fundamental change is feasible today.

PRECISION CONTROL AND MANEUVERING OF THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV) FOR ENTERING A RECOVERY TUBE

Duane Thomas Davis-Lieutenant, United States Navy
B.S., Virginia Polytechnic Institute and State University, 1989
Master of Science in Computer Science-September 1996
Advisors: Robert McGhee, Department of Computer Science
Donald Brutzman, Undersea Warfare Academic Group

Because of range limitations imposed by speed and power supplies, covert launch and recovery of Autonomous Underwater Vehicles (AUVs) near the operating area will be required for their use in many military applications. This thesis documents the implementation of precision control and planning facilities on the *Phoenix* AUV that will be required to support recovery in a small tube and provides a preliminary study of issues involved with AUV recovery by submarines.

Implementation involves the development of low-level behaviors for sonar and vehicle control, mid-level tactics for recovery planning, and a mission-planning system for translating high-level goals into an executable mission. Sonar behaviors consist of modes for locating and tracking objects, while vehicle control behaviors include the ability to drive to and maintain a position relative to a tracked object. Finally, a mission-planning system allowing graphical specification of mission objectives and recovery parameters is implemented.

Results of underwater virtual world and in-water testing show that precise AUV control based on sonar data can be implemented to an accuracy of less than six inches and that this degree of precision is sufficient for use by higher-level tactics to plan and control recovery. Additionally, the mission-planning expert system has been shown to reduce mission planning time by approximately two thirds and results in missions with fewer logical and programming errors than manually generated missions.

INTERNETWORKING: INTEGRATING IP/ATM LAN/WAN SECURITY

Ronald M. Dennis-Lieutenant, United States Navy
B.S., University of Washington, 1988
Master of Science in Information Technology Management-September 1996
Advisors: Don Brutzman, Undersea Warfare Academic Group
Rex Buddenberg, Department of Systems Management

Computer and network security is a complex problem and one that is not solely restricted to classified computer systems and networks. Accelerating trends in networking and the emphasis on open and interoperable networks has left many unclassified systems vulnerable to a wide variety of attacks. Computer and network professionals must understand the scope of security, recognize the need for security for even unclassified systems and then take steps to protect their systems.

Transmission of static passwords in plaintext over the Internet is one of the most widely publicized network vulnerabilities. One-time password mechanisms (such as S-Key) or other secure network access mechanisms (such as Kerberos) have been recommended to improve access security for computer systems connected to the Internet.

This thesis examines many of the issues that must be addressed when assessing the need for computer and network security. This work provides the results of a site security survey for the unclassified IP/ATM LAN in the Systems Technology Lab at the Naval Postgraduate School. These results highlight new security vulnerabilities and strengths that occur when standard Internet Protocol (IP) local-area networks (LANs) are internetworked with Asynchronous Transfer Mode (ATM) wide-area networks (WANs). Finally, we examine the feasibility of the Kerberos authentication protocol for remote plaintext password protection and provide recommendations for additional work.

INTERNETWORKING: AUTOMATED LOCAL AND GLOBAL NETWORK MONITORING

Evan B. Edwards-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1983
Master of Science in Computer Science-September 1996
Advisor: Don Brutzman, Undersea Warfare Academic Group
Second Reader: Lou Stevens, Department of Computer Science

Commercial applications for network monitoring are expensive and therefore not widely available to the majority of network users. Public domain network monitoring software is generally effective in the hands of an expert but difficult to use by the common user because of its command line driven interface. It is a basic tenet of this thesis that network performance and security can be improved if all network users had easy-to-use network monitoring tools available and were encouraged to use them frequently. In this thesis, *ping, traceroute,* and *nslookup* were integrated with the familiar user-friendly interface provided by the World Wide Web (WWW) and HyperText Markup Language (HTML) in both automated and interactive versions. These easy to use monitoring tools were evaluated in several working environments at the Naval Postgraduate School and the Monterey Bay Area Network. *ping, traceroute* and *nslookup* can now be performed in one-sixth of the time previously required for an expert user. Current network status is now readily available and can be validated at any time through the use of the applications developed in this thesis.

INTERNETWORKING: IMPLEMENTATION OF MULTICASTING AND MBONE OVER FRAME RELAY NETWORKS

Ridvan Erdogan-Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1989
Master of Science in Computer Science-September 1996
Advisors: Don Brutzman, Undersea Warfare Academic Group
Michael Zyda, Department of Computer Science

The major problems addressed by this thesis research are how to implement multicast over the Monterey BayNet to enable live audio/video for distance learning, how to safely integrate regional Frame Relay multicast with the global MBone, and how to monitor multicast connectivity over the Monterey BayNet.

To implement multicast and MBone over the Monterey BayNet without using dedicated multicast servers, we enabled Protocol Independent Multicast (PIM) protocol on already-installed Frame-Relay-capable routers. By implementing multicast over Monterey BayNet, we show that the current MBone software provides the same performance that it provides on regular Internet connections even on low-speed (128Kbps) Frame Relay network connections and low-cost personal computers. In order to control the scope of the regional multicast and to safely integrate regional Frame Relay multicast with the global MBone, we used administratively controlled multicast group address (224.0.1.20) in addition to the use of time-to-live (TTL) control mechanism. This eliminates global duplication of multicast packet delivery.

Public-domain multicast monitoring tools are used to monitor the multicast connectivity through internetworks. Since these tools are available only to UNIX-based platforms, they cannot be used by the regional sites that mostly have Windows and Macintosh platforms. We developed Web-accessible multicast monitoring pages in order to meet the multicast monitoring needs of the regional sites. Participating sites are now able to monitor regional multicast connectivity by accessing these pages, which permits remote problem diagnosis. That was previously impossible. Finally we synopsize firewall requirements for secure and effective use of multicast.

MISSION PLANNING AND MISSION CONTROL SOFTWARE FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV): IMPLEMENTATION AND EXPERIMENTAL STUDY

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The Naval Postgraduate School Autonomous Underwater Vehicle (AUV), Phoenix, has a well developed lower level architecture (Execution level) while the upper, Strategic and especially the Tactical, levels need refinement. To be useful in the fleet an easier means of creating mission code for the Strategic level is required. A software architecture needed to be implemented at the Tactical level on-board Phoenix which can accommodate multi-processes, multi-languages, multi-processors and control hard real-time constraints existing at the Execution level. Phoenix also did not have a path replanning capability prior to this thesis.

The approach taken is to provide Phoenix a user-friendly interface for the autogeneration of human-readable mission code and the creation and implementation of a Tactical level control architecture on-board Phoenix to include path replanning. The approach utilizes Rational Behavior Model (RBM) architectural design principles. This thesis focuses on the Officer of the Deck and replanning at the Tactical level, and refinement of the Captain at the Strategic level. While further testing is necessary, Phoenix is now capable of behaving as a truly autonomous vehicle.

Results of this thesis show that nontechnical personnel can generate Prolog code to perform missions on-board Phoenix. Path replanning and obstacle avoidance software are also implemented. Most important this thesis demonstrates successful operation of all three levels of the RBM architecture on-board Phoenix.

THE STRATEGIC UTILITY OF MINI-SUBMARINES

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Involvement of Special Operations Forces (SOF) in worldwide crises will continue to increase as rising nationalism, religious fundamentalism, rapid population growth, and socioeconomic decline foster Third World instability. With increased employment of SOF, the need for clandestine means of transporting them to areas of conflict rises accordingly.

U.S. Special Operations Command is presently developing a new mini-submarine for maritime special operations called the Advanced SEAL Delivery System (ASDS). This thesis explores concepts for the employment of the ASDS as an undersea mobility platform. The research includes review of mini-sub development, analysis of combat lessons learned, and a close look at existing theater requirements for SOF mobility.

Historical inquiry reveals that mini-subs have often had strategic wartime consequences. Today's coastline and harbor defenses are aided by sophisticated arms, sensors and technology, but are largely oriented to surface and air defense, leaving a virtual underwater blindspot. The undersea is the last frontier where maritime forces can operate in denied areas with relative impunity. The ASDS is the only reliable means of prosecuting a significant number of the targets projected by the theater CINCs. Thus the strategic utility mini-submarines is demonstrated.

INTERNETWORKING: EXTENDING LOCAL-AREA NETWORK (LAN) CONNECTIVITY USING ISDN

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Internetworking is the ability to seamlessly interconnect multiple dissimilar networks globally using the Internet (Brutzman, 96). In order to achieve this network, data links need to provide data speeds which allow the applications to function properly. Many important networked applications require high bandwidth to perform effectively.

This thesis presents an analysis of Basic Rate Interface (BRI) Integrated Services Digital Network (ISDN) as a data link technology for extending Local Area Network (LAN) connectivity. Hardware and software capabilities are presented in detail. A representative "ISDN user needs analysis" is also provided. A study is made of an ISDN installation and implementation to determine if ISDN is a viable solution to extending LAN connectivity.

Considerations of particular importance include Internet Protocol (IP) compatibility, bonding separate channels to act as a single 128 Kbps logical channel, and native support for IP multicast addressing. Experimental results indicate that ISDN meets most essential requirements.

INTERNETWORKING: TECHNICAL STRATEGY FOR IMPLEMENTING THE NEXT GENERATION INTERNET PROTOCOL (IPV6) IN THE MARINE CORPS TACTICAL DATA NETWORK

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The Marine Corps must architect a tactical internet based on a software technology that is in transition–the Internet Protocol (IP). Development of the Marine Corps' tactical internetworking system (Tactical Data Network or TDN) is

progressing concurrently with the global Internet community's development of the Next Generation Internet Protocol (IPv6). Current (IPv4) and next generation (IPv6) versions of the Internet Protocol can together meet the tactical internetworking needs of the Marine Corps.

IPv4 provides universal interoperability with other networking technologies and support for a wide range of services now, but without enhancements IPv4 cannot meet the long-terms needs of evolving tactical applications. IPv6 is needed to meet emerging requirements (such as secure mobility) but is not yet ready for implementation in the Tactical Data Network. Therefore the Marine Corps must build the tactical internet architecture using IPv4 and incorporate IPv6 improvements when transition is possible.

Marine Corps commitment to IP is essential to ensure universal interoperability and hardware-independent evolution of tactical applications and networking technology. This work presents a tactical IP addressing plan for TDN that works with IPv4 and also facilitates smooth transition to IPv6. In concert with the other military services, the Marine Corps must develop a strategy for migrating the joint tactical internet to IPv6. The future viability of the Tactical Data Network depends on the Internet Protocol.

STRATEGIC SEALIFT PROTECTION IN A MAJOR REGIONAL CONFLICT
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This thesis examines the North Korean threat to U.S. strategic sealift in a single major regional conflict (MRC) on the Korean peninsula. The focus of this campaign level analysis is the ability of U.S. and Korean maritime patrol aircraft (MPA) to intercept North Korean Romeo-class attack submarines as they operate in South Korean waters. An MPA search model is developed which details current tactics and operating parameters for the P-3C Orion patrol aircraft. Results obtained from this model are expressed as the probability that a North Korean submarine in a special geographic sector will be detected and destroyed on any given day of the campaign. Two alternative means of conducting anti-submarine operations in the Korean MRC are also presented. Campaign and tactical level recommendations are made based on the information provided by the analysis.

INTERNETWORKING: MULTICAST AND ATM NETWORK
PREREQUISITES FOR DISTANCE LEARNING
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The Internet, the World Wide Web and the Multicast Backbone (MBone) have been used in a variety of ways for distance learning. Video TeleConferencing (VTC) classrooms have obvious value and utility but they are limited to communicate with only a small number of similar VTC facilities. We are most interested in open solutions which take advantage of the global Internet. Therefore the problem addressed by this thesis is to evaluate the specific benefits and drawbacks of Internet technologies in support of distance learning.

This thesis includes a detailed examination of MBone, Asynchronous Transfer Mode (ATM) and the Distributed Interactive Simulation (DIS) protocol from the perspective of distance learning.

One result we found is that MBone can be used successfully for distance learning purposes despite common constraints of limited (128 Kbps) bandwidth. A further result is that an MBone classroom can be 42% as expensive as a VTC classroom if an *SGI Indy* is used and 12% as expensive as a VTC classroom if a PC is used in the classroom. Consequently many schools can afford Internet-based distance learning using the solutions presented in this thesis even though they cannot afford VTC rooms.

INTERNETWORKING: ECONOMICAL STORAGE AND RETRIEVAL OF DIGITAL AUDIO AND VIDEO FOR DISTANCE LEARNING

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Previous research has shown that it is possible to use the Internet's Multicast Backbone (MBone) and associated audio/video software for the purpose of Distance Learning. As more education is performed online, the need arises to be able to view the content at the user's convenience. Through experimental testing, this thesis investigates the usefulness and feasibility of applying networked recording and storage of digitized audio and video, all via the MBone for distance learning.

Large, distributed organizations such as the Naval Service can economically benefit from use of the MBone and its associated tools. To date, Navy and Marine Corps projects using video teleconferencing have not exploited the vast possibilities provided by the Internet and the MBone. This thesis takes distance learning one step farther and combines MBone audio/video with the new recording tool called the Multicast Backbone Video Conference Recorder (MBone VCR). This enables distance learning as a viable replacement to on-site training. It is technically feasible and economically supportable to record the digital media that results from an MBone session used for a distance learning program. That stored information can then be used repeatedly and easily updated to support changing curricula and information. Problems and network-accessible solutions are demonstrated in this case study on use of the MBone VCR as a usable remote educational tool.

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